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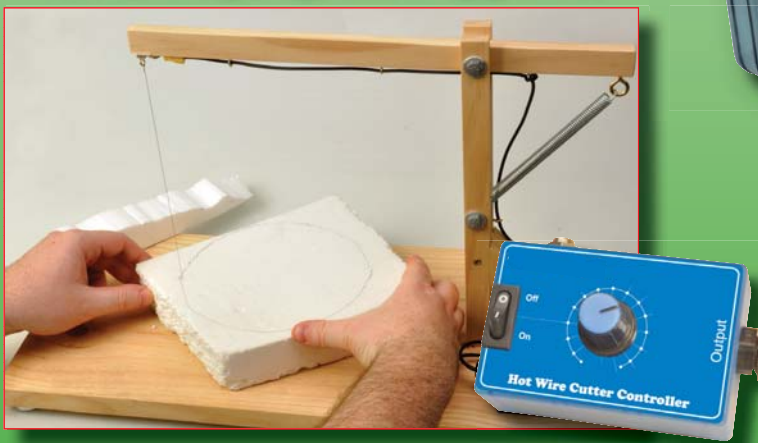

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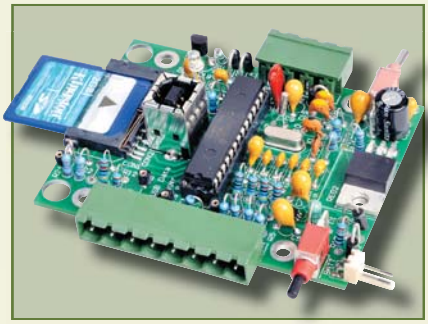

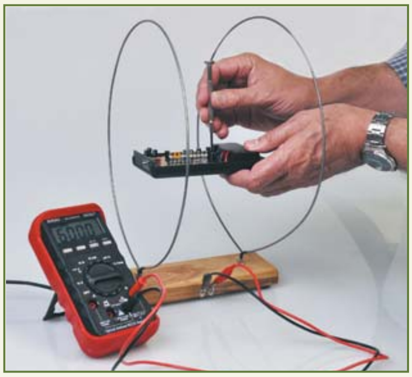

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Series and Features

Regulars and Services

Our January 2013 issue will be published on Thursday 6 December 2012, see page 80 for details.


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These educational electronic robot kits make a great introduction to the exciting world of robotics. Some require soldering. See website for details
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Kits for Electronics Enthusiasts

18m IR Light Barrier Kit
Cat. KG-9096

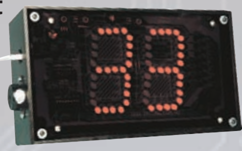
This kit consists of an infrared receiver and transmitter and will shoot an IR beam 18 metres. Use with driveway or pathway monitoring, automatic garage door triggering or shop front/office entry monitoring. Includes a daylight filter to eliminate false triggering in sunlight. The receiver's relay can be used to trigger an alarm, siren or relevant triggering device.

- TX requires 9VDC 90mA; RX 12VDC 100mA.

£14.50*

Also available:
50m IR Light Barrier (KG-9196 £18.25)

Annunciator Kit
Cat. KC-5420

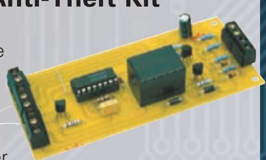


Need people to take a number when waiting to be served? This electronic signalling device has digits 75mm high, each using 28 high intensity red LEDs. The numbers display from 00 to 99 is incremented by pressing a button on the separate small control box. Kit includes case, PCB and electronic components. Requires 12VDC power.

- Main Box Size: 197 x 113 x 63mm
- Control Box size: 76 x 46mm

£21.75*

Driving Light Anti-Theft Kit
Cat. KC-5337



Protect your expensive Driving or Fog Lights that are otherwise vulnerable to theft. Simply connect it to the power cable on the lights you want to protect, and to your car alarm or siren and you are set. If the lights are removed or the cable is cut, the alarm will sound.

- Kit includes: PCB, wire and electronic components

£7.25*

RFID Security Module Receiver Kit
Cat. KC-5393

Radio Frequency Identity (RFID) is a contact-less method of controlling an event such as a door strike or alarm etc. An "RFID Tag" transmits a unique code when energised by the receiver's magnetic field. As long as a pre-programmed tag is recognised by the receiver, access is granted. This module provides normally open and normally closed relay contacts for flexibility. It works with all EM-4001 compliant RFID tags.

- Kit supplied with PCB, tag, and all electronic components

£36.25*

Infrared Floodlight Kit
Cat. KG-9068

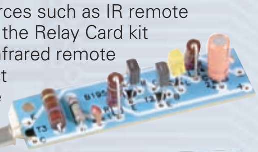
Let your CCD camera see in the dark! This infrared light is powered from any 12-14VDC source and uses 32 x infrared LEDs to illuminate an area of up to 5m (will vary with light conditions).

- Kit is supplied with silkscreened/ gold plated/ solder-masked PCB, 32 x Infrared LEDs and all electronic components
- PCB: 74 x 55mm

£11.00*

Note: Not suitable for colour CMOS cameras

Infrared Detector Kit
Cat. KG-9086



This kit will switch on a LED when it detects infrared light from sources such as IR remote controls. Connect it to the Relay Card kit KG-9142 to make an infrared remote controlled relay. Project requires 9VDC. Can be battery powered.

- Kit supplied with Kwik Kit PCB, Infrared receiver and all electronic components
- PCB size: 55 x 15mm

£3.75*

4Ch CCTV Camera Switcher Kit
Cat. KC-5316

This project allows you to keep an eye on what's happening in each camera's field of view. It can accommodate up to 4 cameras and features variable scan rate as well as a pause button to freeze the scan for specific camera viewing. LEDs on the front panel indicate the camera channel being monitored. 12VDC 110mA required.

- Kit includes case, punched & silk-screened panelling plus electronic components

£21.75*

45 Second Voice Recorder Kit
Cat. KC-5454

This kit easily record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. It also provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14VDC.

- Supplied with silk screened and solder masked PCB and all electronic components
- PCB: 120 x 58mm

£12.75*

POPULAR KITS

Jacob's Ladder High Voltage Display Kit MK2
Cat. KC-5445

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display.

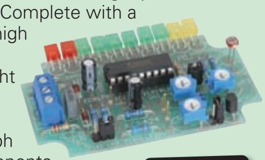
Kit includes PCB, pre-cut wire/ladder and electronic components.

- 12V car battery, 7Ah SLA or > 5A DC power supply required
- PCB: 170 x 76mm

£15.75*

Voltage Monitor Kit
Cat. KC-5424

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0-5V or 0-1V ranges. Complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and electronic components.

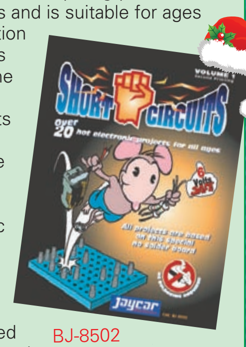


£8.50*

- 12VDC
- PCB: 74 x 47 mm
- Recommended box: UB5 (use **HB-6015 £1.25***)

Short Circuits - Volume 1

This volume will teach you everything you need to get started in electronics and is suitable for ages 8+. We give you the option of buying the book on its own, or together with the accompanying kit that contains the components for each of the 20-odd projects described in the book. Some of the exciting projects include a Police Siren, Electronic Organ, Sound Effects Unit, Light Chaser and many, many more! The full colour 96 page book, is lavishly illustrated with over 100 drawings and diagrams. No prior knowledge of electronics is needed, projects are fun and safe to build.



BJ-8502

KJ-8504

Short Circuits Book
BJ-8502 £3.75

Short Circuits Project Kit
KJ-8504 £12.50

Short Circuits Book and Project Kit
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EPE EVERYDAY PRACTICAL ELECTRONICS

Happy birthday to the LED!

This autumn sees the fiftieth anniversary of the first commercial visible-spectrum light-emitting diode – the LED. When US giant General Electric (GE) first offered their red (only) LEDs back in October 1962 they cost a staggering $260 – roughly equivalent to $2000 in today's money. In spite of the high price, the potential for such a compact and reliable light source was obvious. The resulting demand for the device lead to the classic electronic component virtuous circle of higher production runs, better quality and rapid price drops. LEDs quickly became the default light source for a whole host of electronic equipment.

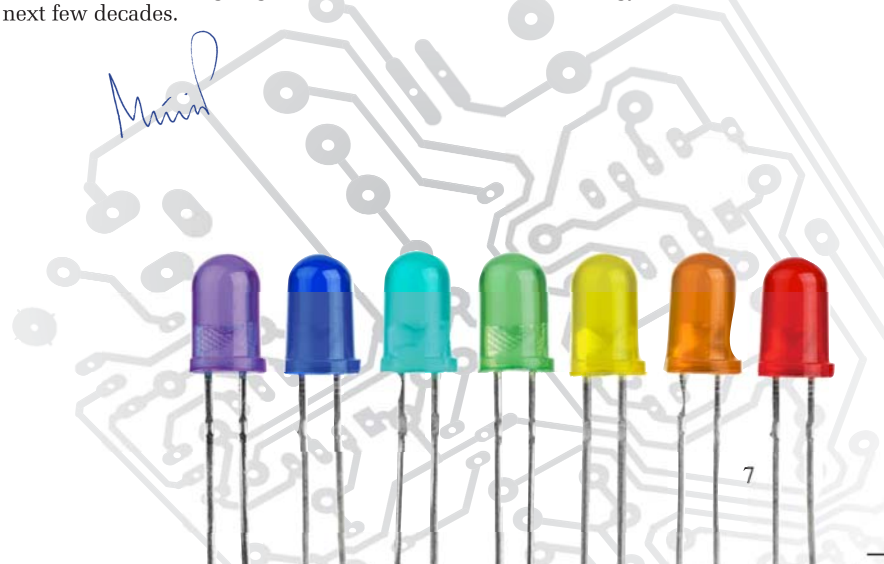
Over the decades, improvements in understanding and manipulating semiconductors meant that LEDs became available in increasingly shorter light wavelengths – yellow, then green and finally blue, purple and even ultraviolet. What set these devices apart was that they were truly electronic. In a traditional incandescent light bulb, so much current is passed through a conductor that it heats up to the point where it gives off light. Not so in an LED, where the cool-running LED gives out light at normal room temperature through the recombination of positive charge carriers – 'holes' – and equal, but opposite negative charge carriers – electrons. In other words, there is a direct electrical-to-optical energy conversion, without any intervening thermal process.

This gives LEDs several advantages – they are efficient, they are easy to control with other electronic devices and their lack of heat production means they can be reliably produced in small sizes.

Despite their age, LEDs are still evolving in exciting directions. The latest important incarnation of the LED is the OLED, or organic LED. As their name implies, they use organic semiconductor compounds to emit light. These are particularly important for making various types of displays and have unique properties that will probably make them one of the most common types of display technologies in the near and medium future.

They can be cheaply inkjet printed on to many different types of substrate, which will make them more economic to produce than LCD displays. A real change form the past is that OLED displays are happy to be fabricated on to flexible materials, possibly even special types of cloth – providing unlimited possibilities for the ultimate designer t-shirt!

There are still challenges to be overcome with OLEDs – for example, the efficiency and lifespan of blue OLEDs is much poorer than for other colours, which is a real challenge for RGB screen manufacturers. Also, they are easily damaged with water, which might make washing hi-tech t-shirts a challenge! However, these are all issues which are being tackled head on, and I am sure we are going to see a lot more of OLED technology over the next few decades.



NEWS

A roundup of the latest Everyday News from the world of electronics

Philips approach to 3D TV – report by Barry Fox

Philips is now a minority shareholder in its own TV business. TPV, the Chinese monitor manufacturer, owns a 70% share of new joint venture TP Vision, and Philips of the Netherlands owns 30%. Innovation is from research centres in Eindhoven and Bruges, software from Bangalore and mechanical design is done in Taiwan, in Taipei, and some in China.

3D needs to lose its goggles

I spoke with CEO Maarten de Vries (ex-Philips) recently: 'I think 3D has been hyped too much' he admitted. '3D is included in our sets, but we don't see consumers using it. We think 3D will only really take off when it is goggle-less. We don't feel people will sit in a living room wearing glasses.

'Currently, we are selling 3D as a feature of large-screen sets. When people buy the sets they get 3D included. But we don't mention 3D – that's on purpose and by design.'

Although several companies, eg, Toshiba, are already selling autostereoscopic, no-glasses TV, the sets are absurdly expensive and the pictures are poor. The most impressive demonstrations have been of Philips prototypes, which aren't for sale.

Says de Vries: 'Over the last few months we have seen significant improvements in goggleless 3D. It could be big now, but not at the current price point. Goggleless will take off when it is at the same price point as current sets, around 2000 euros.

'We don't see that happening next year, but it will come and when it does it will be the true breakthrough. Results in the labs with our proprietary technology are extremely impressive.'

Autostereo technology

Philips is understandably secretive about what's proprietary, but a patent search gives clues. The company has filed over 200 patents worldwide on 'autostereoscopic' TV. Some give a useful re-cap on the basics of no-glasses 3D, and the technical challenges.

In the most basic autostereo system, each 3D view (for the left and right eyes) is sliced into vertical strips that alternate across the screen width; left-view slice, right-view slice, left-view slice and so on. The screen is covered (during manufacture) with a grid of vertical lenticular strips, each strip being a semi-cylindrical lens. Each lenticular strip covers a pair of vertical image slices, and optically directs them in different directions, so that a viewer's left eye sees only the left image slices and so on.

The viewer must, however, be in a 'sweet spot' directly in front of the screen. Although this is acceptable for computer screens and mobiles, where the viewer's position is predictable, it is no good for TV screens in rooms.

TP Vision CEO Maarten de Vries (ex-Philips)

In a more advanced system, as already used in currently available no-glasses TVs, the 3D image is sliced into a group of multiple (typically nine) view pairs and each lenticule covers one of these image groups. As a viewer's head is moved from left to right, the left and right eyes see a series of successive, different, stereoscopic views. The result is a 3D effect from different positions, with a look-around impression. The downside is that horizontal resolution is reduced.

Resolving the resolution issues

In 1997, Philips' UK Lab filed patents on making the lenticular lens from electro-optical material so that its optical effect can be made to disappear in 2D mode. The screen still suffers resolution loss in 3D mode, however. Increasing native screen resolution of the screen from 1920 × 1080 Full HD to Quad HD 3840 × 2160 pixels, addresses this problem, but adds considerably to the cost.

A more economical approach, under development by Philips since 1995, is to slant the lenticules diagonally across the screen so that the resolution loss is shared between horizontal and vertical.

Another trick is to arrange the screen pixels in pairs of sub-pixels (two red, two green and two blue) and rapidly switch between them; eg, at twice the normal TV display rate of 60Hz. The screen then displays a succession of different image views or 'sub-frames', which the viewer's eyes blend together into a seamless spread of left and right views. The screen is thus effectively displaying twice as many 3D views as it could normally display, without halving the resolution.

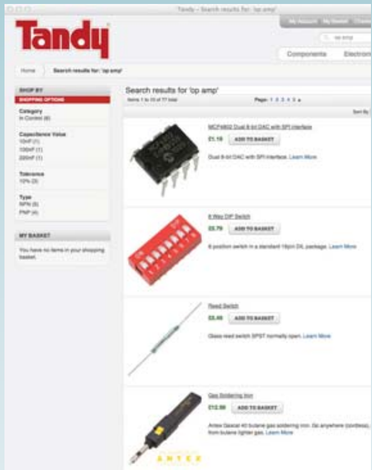
Ironically, this is possible only because of the advances in rapid refresh LCD technology which have been driven by the need for an LCD screen that can display a double speed sequence of left and right images for active-shutter glasses 3D.

Tandy relaunched online

Tandy brand is relaunching in the UK, dedicated to the online supply of components to hobbyists in the UK and some EU states. Tandy promises competitive pricing and a flat-rate delivery charge of £1 per order (UK), regardless of size.

Tandy stores were familiar on British High Streets in the mid-1970s, selling own-label gadgets, audio, toys, electronics and components. A downsized retail chain became mobile phone outlets for Carphone Warehouse over 10 years ago. Chief executive Darren Grant of ADSL Nation Ltd, the new owners of the Tandy name, is a keen electronics enthusiast and he told *EPE* that the upsurge in hobby electronics meant the time was ripe to resurrect the Tandy brand.

'It allows constructors to buy individual components at fair prices without minimum order values or minimum pack sizes. There is no barrier to just selecting a few small parts for a one-off experiment and get them in the post a day or two later,' he says.



Back to challenge RS and Farnell? Tandy are now selling electronic components and kits in the UK

Tandy's new website contains an expanding range of components, including the usual staple project components, plus Raspberry Pi, Arduino and more. It can be browsed at: **www.tandyonline.co.uk**

Retro technology lands on Mars

Imagine you are going to the considerable expense and trouble of putting a research vehicle as large as the *Mars Curiosity* robotic rover on the 'Red Planet'. Plus, you've got the technical and financial muscle of NASA behind you.

What system would you choose to control the vehicle and collect data? The latest all-singing, all-dancing, terahertz clocking parallel processor made out of diamonds, secret semiconductors and all the gee-whizzery available to a superpower's space agency?

The Mars Curiosity rover – controlled by a PowerPC processor (Image courtesy of NASA/JPL-Caltech)

Well, apparently not – according to a report from semiconductor giant Intel, experience has taught space engineers that when it comes to building systems to run in space the two most important characteristics are familiarity and reliability.

Familiarity means that when it comes to building software-based systems you can anticipate problems and have repairs, software patches and strategies on hand to correct errors and failures as quickly and painlessly as possible. Likewise, reliability is something that comes with experience and repeated testing and constant improvements. You can only meet these two requirements with systems that have been put through years of work, and for that reason the chip chosen was a humble 200MHz PowerPC 700 computer processor that first appeared in a 1997 Apple Macintosh and PowerBook G3 laptops. At best, they have a tenth of the processing power that consumers have in today's notebook computers, or even smartphones.

Apart from proven general reliability, these chips have another important characteristic. They can withstand radiation exposure. Most radiation-hardened chips could only withstand up to 500 kilorads, but the PowerPC chip chosen can handle a megarad of radiation exposure, twice the required amount of radiation resistance.

So, if you want a NASA-spec computer control system, all you need to do is wait for a 15-year-old computer to appear on eBay!

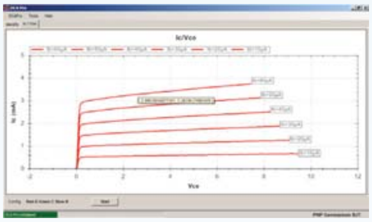
PEAK Atlas DCA Pro

Peak Electronic Design Ltd has announced a new product, the 'Peak Atlas DCA Pro' (model DCA75). The DCA Pro features a graphics display, USB communications, PC Software and an enhanced component identification library.

The DCA Pro supports many components, including: transistors (silicon/germanium types, including Darlingtons); MOSFETs (enhancement and depletion mode types); JFETs; IGBTs; diodes and diode networks; LEDs; Zener diodes; and voltage regulators (measures regulation voltage, drop-out voltage, quiescent current).

The instrument can be used standalone or connected to a PC. Either way, the DCA Pro will automatically identify the component type, identify the pinout and also measure a range of component parameters such as transistor gain, leakage, MOSFET and IGBT threshold voltages, *PN* characteristics and much more.

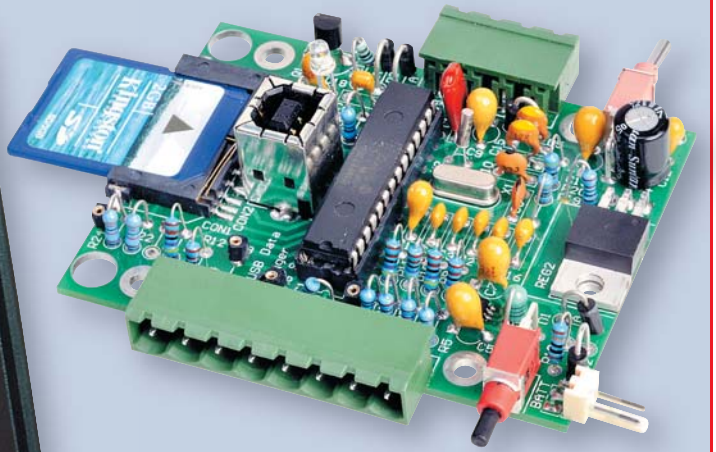
The price is £115.95 (incl VAT), more information at: **www.peakelec.co.uk**



Above: *the graphic screen shows a schematic symbol on its display for the component being tested – here, a TIP110 Darlington. The symbol shows both internal transistors, the shunt resistors and the free-wheeling diode.* ***Below:*** *An example of the output characteristics measured for a connected OC71 germanium transistor on the DCA Pro when connecting by the supplied USB cable to a PC*

Tiny humidity/temp sensor

Sensirion has launched the world's smallest humidity and temperature sensor. The SHTC1 is specifically designed for mobile devices where size is critical. At just 2 × 2 × 0.8 mm, the sensor is based on CMOSens technology, which allows the sensor and the signal processing electronics to be combined on a single silicon chip with a supply voltage of only 1.8V.



Based on a PIC micro, this simple project can log lots of data to a memory card. It can read from many types of digital and analogue sensors, and features a real-time clock and calendar to 'time-stamp' the data. It has a USB port and comes with a PC host program, allowing you to configure the sensors, change settings and charge the battery.

By MAURO GRASSI

Universal USB Data Logger – Part 1

THIS low-power *USB Data Logger* is useful for a myriad of applications, especially where you need to log data over a long time period. It logs to an MMC/SD/SDHC memory card (with FAT file system), which means you can store up to 32GB of information. That's a lot of logged data.

The average current consumption is typically less than 1mA and it can be powered using two AAA cells (either NiMH rechargeable types or alkaline). Alternatively, it can be powered from a USB port on a PC, or an external 5V to 7V DC supply.

If NiMH cells are fitted, these will be recharged whenever the device is connected to a PC (via the USB port) or powered from an external DC supply.

The logger can accept inputs on up to eight lines, with a maximum of up to six digital lines and up to four analogue lines. Many different types of analogue and digital sensors can be used and the digital inputs can also be used for frequency measurement or event counting. It is even possible to connect a GPS (Global Positioning System) module to log geographical coordinates.

For storage, just about any MMC, SD or SDHC memory card can be used. They are ideal for this application because they are cheap, reliable, have low power requirements and are available in capacities ranging from 16MB up to 32GB.

Typical applications

A typical application for this device would be to log data from a remote weather station. For example, let's say you wish to monitor a weather station with humidity, wind speed, rainfall, temperature and barometric pressure sensors. With this device, you can log their values over many days into a CSV (comma separated values) file on the memory card. Then, when you've finished logging, you can connect the *USB Data Logger* to your Windows-based PC and download the file via the USB port.

Alternatively, you could simply remove the memory card and use a memory card reader. The downloaded log file can then be opened using Open Office or Microsoft Excel. From there, it's easy to graph the readings and analyse them.

Another use involves diagnosing a problem with a car engine. You can monitor the relevant engine sensors and log them while driving. Later, analyse the data to locate the problem. You can even log your route if you connect a GPS module to the *USB Data Logger.*

These are just two examples and there are lots of other uses, including monitoring industrial processes, collecting all sorts of field data, troubleshooting and testing. We've made the logger as flexible as possible by making it compatible with a wide range of sensors.

USB Data Logger: Main Features

- Uses an MMC/SD/SDHC memory card (FAT file system) for up to 32GB of storage capacity.
- USB full speed (12Mbps) interface for connection to a PC.
- Host PC program for Windows-based PCs.
- Up to six digital sensor inputs with support for I^2C (Inter-IC Communications) and One Wire Dallas protocols. Also supports a full duplex serial port UART (universal asynchronous receiver transmitter) interface (eg, for connecting a GPS module).
- Up to four analogue inputs (two shared with digital inputs) with 12-bit A/D conversion and ±5% accuracy. The analogue inputs can also accept frequency signals up to 192kHz or can function as a 32-bit event counter.
- Custom scripting language allows a wide range of different digital sensors to be used.
- Low power consumption (around 1.5mA in standby mode).
- Flexible power options – can be battery-powered (using two AAA cells), USB powered or powered from an external 5Vto-7V DC power source.
- NiMH cells can be trickle-charged using USB power or an external power source.
- An external voltage reference can be connected for greater than ±5% accuracy on the analogue inputs.
- Battery protection to prevent over-discharge.
- Includes an on-board real-time clock calendar (RTCC).

PIC microcontroller

The *USB Data Logger* is built around a PIC18F27J53-I/SP microcontroller (IC1). This is an 8-bit microcontroller with 128KB of program (Flash) memory and 3KB of SRAM (static random access memory). It's a 28-pin device and is well suited to this application due to its impressive list of internal peripherals and low price.

The following peripherals are used in this project: the USB device controller; the integrated RTCC (real-time clock calendar), with separate oscillator circuit; the SPI, I^2C and UART serial peripherals; ten output compare/capture peripherals; one of three comparators; the 12-bit A/D (analogue-to-digital) converter with internal band gap reference; and the comparator voltage reference.

SPI (serial peripheral interface) is a four-wire (plus ground) serial communication protocol, while the I^2C (inter-IC communications) and UART (universal asynchronous receiver/transmitter) peripherals use two wires.

Other microcontroller features which this project benefits from include the DMA (direct memory access) support for the SPI peripheral, the low-power 'sleep' modes and the very useful PPS (peripheral pin select) feature.

Sensor support

The *USB Data Logger* supports a wide range of sensors and these are connected via terminal block CON4. There are four digital pins (D0-D3), two analogue pins (A2-A3) and two analogue/digital pins (D4/A0 and D5/A1). These latter pins can be used for either digital or analogue sensors (but not both). Table 1 shows the pin configurations – do check the comments.

Digital sensors

The *USB Data Logger* is extremely versatile in that it can accept inputs from I^2C, One Wire Dallas and serial port (UART) digital sensors. Using digital sensors can reduce A/D conversion errors compared to sensors connected to the analogue inputs (see below). This is because digital sensors usually contain their own A/D converters, which are optimised for the task.

I^2C and One Wire Dallas sensors must be connected to digital inputs/outputs D0 to D3 (pins 1 to 4 of CON4). The great thing about using I^2C sensors is that you can connect many different sensors to the same I^2C bus, which consists of just two lines. In fact, as many as 127 I^2C devices can be connected to the same bus!

Similarly, only one line is required to connect many different One Wire Dallas sensors to the *USB Data Logger*. As the name suggests, One Wire Dallas sensors only require the use of one pin.

IC1's PPS feature allows the appropriate internal communications peripheral to be routed to whichever sensor lines the digital sensor(s) are connected to. The supplied Windows-based host program allows you to configure the firmware for the types of sensors connected to the various inputs.

Finally, there is support for a configurable, full-duplex serial port (via the UART peripheral). Among other things, this allows a GPS module (eg, the EM-408 – Altronics K-1131) to be connected to two of the digital inputs (for bidirectional signalling). Doing this will allow position information to be logged, as well as keeping the real-time clock synchronised with GPS time, guaranteeing accurate timekeeping (more on this next month).

Analogue sensors

The simplest analogue sensors output a voltage that's directly proportional to the measurement value. For example, a ratiometric temperature sensor outputs a voltage that varies linearly with changing temperature. Accelerometers with analogue outputs also vary their outputs linearly in response to acceleration.

Up to four analogue sensors with variable voltage outputs can be used with the *USB Data Logger.* Inputs A0 and A1 are for sensors with low-voltage outputs (0V to 3.6V), while A2 and A3 are for sensors with high voltage outputs (0V to 13.8V).

These two sensor input pairs differ only in the voltage dividers used at the inputs. While low-voltage sensors can be connected to A2 and A3, the measurement resolution will be poor.

Internal voltage reference

The reduced voltages from the analogue sensors are fed to inputs AN0 to AN3 of IC1 and are digitised using a 12-bit A/D conversion process. Normally, the accuracy of this 12-bit A/D conversion depends on the exact supply voltage to the microcontroller.

For this reason, the firmware checks the supply voltage to IC1 regularly using an internal band gap reference (1.2V ±5%) and adjusts the A/D conversion values accordingly. Note, however, that due to the tolerance of the reference voltage (ie, 1.14V to 1.26V), the digitised values also have a possible error of ±5%, although it will typically be better than this.

If you require an accuracy better than ±5%, for the analogue sensors, a precise voltage reference can be connected to one of the four analogue inputs. This reference can then be used to accurately measure the other analogue sensors. Just how this is done will be explained in Part 2 next month.

Frequency and counter inputs

The *USB Data Logger* can also measure the frequency applied to any of the six digital inputs (D0 to D5), at up to 192kHz. Inputs D0 to D3 can handle signals from 0V to 5V, while D4 and D5 can handle signals from 0V to 3.6V. The reason that inputs D0 to D3 can handle higher voltages is that IC1's input transistors are 5V-tolerant on those pins.

If you require the circuit to tolerate even higher voltages, the voltage dividers at inputs D4/A0 and/or D5/A1 can be changed to suit. This is also true for the analogue inputs.

As well as measuring frequency, the six digital inputs (D0 to D5) can also act as simple counters, logging the number of positive or negative edge transitions that occur. In this mode, the counters are 32 bits, so the maximum number of events that can be counted is over four billion per input.

Circuit details

The full circuit diagram for the *USB Data Logger* is given in Fig.1. It consists of the microcontroller IC1, a memory card socket (CON1), a couple of power supply ICs (REG1, REG2) and a handful of minor components.

The sensors are connected to eight I/O pins of IC1 (RB4 to RB7 and ANO to AN3) via terminal block CON4.

I^2C and One Wire Dallas sensors must be connected to digital inputs/outputs D0 to D3 (pins 1 to 4 of CON4). These lines all have 4.7kΩ pull-up resistors to the +3.3V supply rail, which is required for this type of sensor, which have open-collector outputs, allowing multiple devices to share the same bus.

Inputs D4/A0 and D5/A1 (pins 5 and 6 of CON4) use a voltage divider made up of 470Ω and 4.7kΩ resistors. This means that these two inputs can accept analogue sensor output voltages up to 3.3/(4700/5170) = 3.6V. The low-value series resistors (470Ω) do not preclude the use of digital sensors with these pins.

By contrast, the A2 and A3 analogue inputs use voltage dividers made up of 15kΩ and 4.7kΩ resistors. This gives a maximum sensor voltage range of 3.3/(4700/19,700) = 13.8V (since the voltage fed to IC1 cannot exceed 3.3V). The 10nF capacitors form *RC* filters with the 470Ω and 15kΩ resistors to reject noise on the analogue inputs.

Memory card interface

CON1 is the memory card socket and this has an internal normally open (NO) switch that's used to detect when the memory card is inserted. A 33kΩ pull-up resistor normally holds the SDS1 line high, but this is pulled to ground when the card is inserted and the switch is closed.

The memory card is powered from the 3.3V rail and this is connected directly to pin 4 of the socket. This negative side of the supply is switched by MOSFET Q1 (2N7000) as its drain (D) is connected to pins 3 and 6 (GND) of CON1.

Charge pump

This FET (Q1) needs at least 4.5V applied to its gate (G) to guarantee that it turns on fully, which is higher than the main power supply rail (3.3V). Therefore, its gate is driven by a charge pump circuit based on diodes D3 and D5, a 10nF capacitor and a 4.7µF tantalum capacitor.

To power up the memory card, IC1 drives this charge pump circuit using a square wave from pin 13 (RP13), generated by one of its output compare (OC) peripherals. At the same time, D5's anode (A) is pulled high by pin 17 of IC1 (which also controls LED1).

It works as follows. When the signal at RP13 is close to 0V, the 10nF capacitor quickly charges via D5 to about 3.3V – 0.6V = 2.7V (0.6V is the drop across D5). Then, when the signal at RP13 subsequently goes high (ie, to 3.3V), the junction of this capacitor with D5 is immediately pulled to 3.3 + 2.7 = 6V. At this point, D3 conducts, charging the 4.7µF tantalum capacitor.

The charge on the tantalum capacitor builds over several cycles until diode D3 no longer conducts, at which point its charge is close to 6V. So the

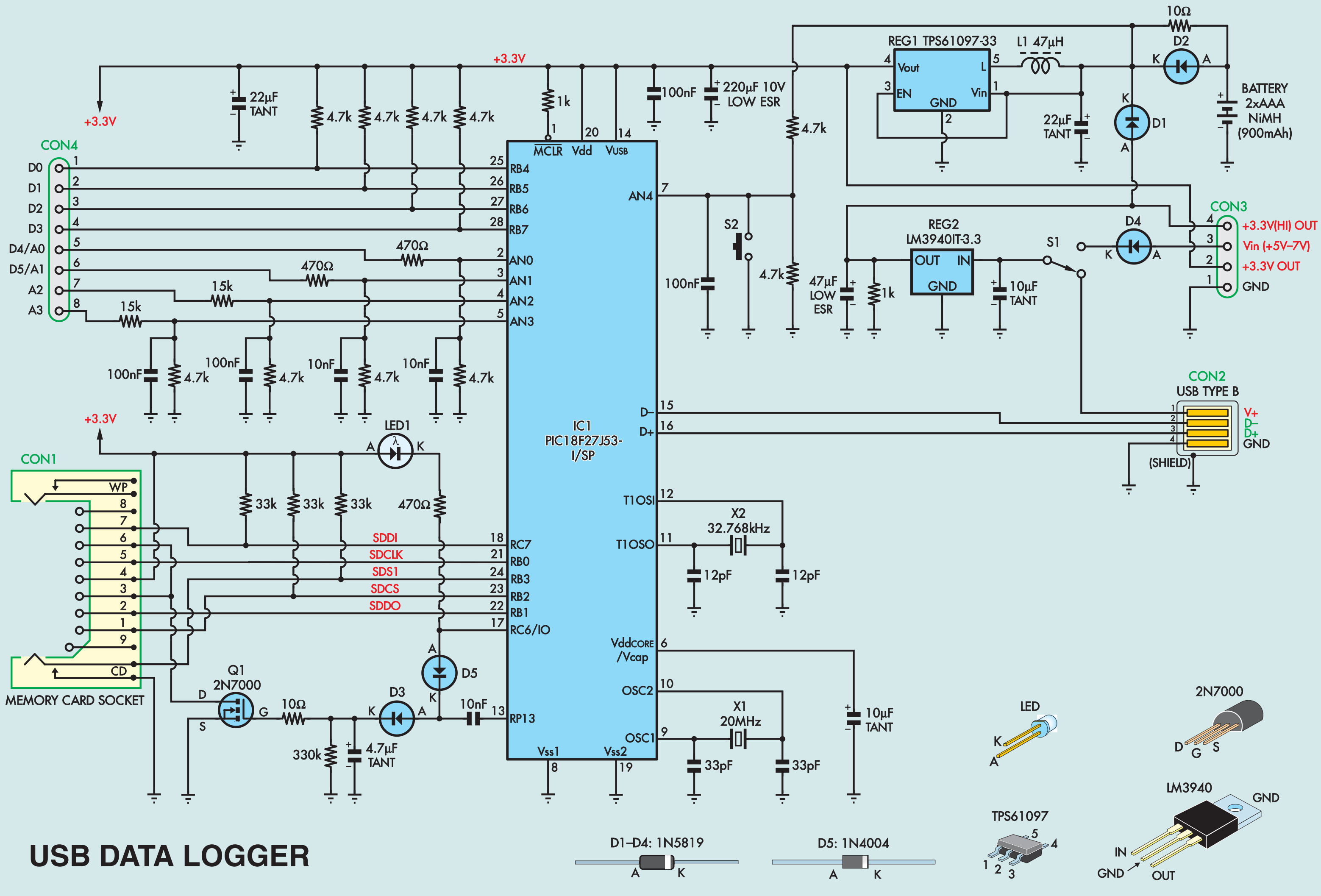


Fig.1: the *USB Data Logger* circuit is based on a PIC18F27J53-I/SP microcontroller (IC1). This accepts digital and analogue inputs via connector CON4 and reads and writes data to a memory card via CON1. IC1 also interfaces to USB socket CON2 via an internal controller, while regulators REG1 and REG2 provide 3.3V supply rails. Power can come from two AAA cells, from a PC or from an external 5V-to-7V DC supply.

Table 1: Pin assignments for CON4			
Pin number	Pin name	Pin function	Pin comments
1	D0	Frequency input/digital input or output	Digital function, 0V to 3.3V signal output, 0V to 5V signal input
2	D1	Frequency input/digital input or output	Digital function, 0V to 3.3V signal output, 0V to 5V signal input
3	D2	Frequency input/digital input or output	Digital function, 0V to 3.3V signal output, 0V to 5V signal input
4	D3	Frequency input/digital input or output	Digital function, 0V to 3.3V signal output, 0V to 5V signal input
5	D4/A0	Digital Input or output/analogue/frequency input	Analogue/frequency input, 0V to 3.6V signal; can also be used for digital functions
6	D5/A1	Digital Input or output/analogue/frequency input	Analogue/frequency input, 0V to 3.6V signal; can also be used for digital functions
7	A2	Analogue input	0V to 13.8V analogue input
8	A3	Analogue input	0V to 13.8V analogue input

circuit 'doubles' the applied voltage (or near enough).

The 6V is high enough to turn on MOSFET Q1 via the 10Ω current-limiting resistor. The associated 330kΩ pull-down resistor ensures that Q1 turns off when there is no longer any drive signal to the charge pump circuit from the microcontroller.

During periods of extended idle time (ie, when not logging for extended periods), the microcontroller goes to sleep and its pin 13 output goes low. As a result, Q1 is off and this turns off the supply to the memory card, to conserve power.

From this, it follows that the higher the logging frequency, the greater the power use; this needs to be considered if the unit is powered solely from a battery. In addition, if the logging interval is very short (ie, less than 5s), power to the memory card will not be turned off. That's because the initialisation sequence for the memory card would take too long and logging events would be missed while initialisation was taking place.

Double function

As well as driving diode D5 for the charge pump, IC1's RC6 (pin 17) output also controls LED1. This flashes briefly whenever logging is turned on or off, and also occasionally flashes whenever logging is enabled.

This LED can also be driven while the charge pump is in operation; in other words, the RC6 pin of IC1 is multiplexed. This doesn't interfere with the charge pump operation, since the firmware automatically adjusts the drive to LED1 and the RP13 output as appropriate.

Memory card SPI connection

The SPI peripheral of IC1 handles communications with the memory card, while high-level software layers add support for a FAT (File Allocation Table) file system. This file system (including both FAT and FAT32) is supported by all common operating systems.

MMC/SD/SDHC cards can be accessed either in their native mode or in SPI mode. The advantage of SPI mode is that the interface is simpler and this makes the hardware layer easy to implement. The penalty is slower transfer speeds, but this is of no consequence here, as SPI speeds are quite adequate for data logging.

IC1 communicates with the memory card using one of the two on-board SPI peripherals, in this case SPI2. It also has hardware support for DMA (direct memory access) for this peripheral, allowing data to be transferred to and from the memory card at the same time as the microcontroller is executing code, making data transfer more efficient.

SPI communication uses a 4-line bus and is capable of full duplex transfers between a host and a slave. The four lines are: SDCS (chip select – active low), SDDO (serial data output), SDDI (serial data input) and SDCLK (serial clock).

In this case, the microcontroller is the SPI master. When the SDCS line is pulled low, the memory card becomes active and listens for commands.

The SPI peripheral is routed via the PPS feature of IC1, so that the SDCLK line is at pin 21 and the SDDI and SDDO lines are at pins 18 and 22 respectively. The latter two are connected (transposed) to the DO (Data Out) and DI (Data In) lines respectively of the memory card. These lines are used to transmit and receive data in conjunction with the clock signal (SDCLK) generated by IC1.

The SPI bus runs at 12MHz in this application, which is the fastest that the microcontroller will allow. Note that the SDCS line is pulled high by a 33kΩ resistor to disable the memory card by default (eg, when

Table 2: Supply connections for CON3		
Pin number	Pin name	Pin function and comments
1	GND	Ground (0V)
2	+3.3V	+3.3V rail from REG1; capable of supplying up to 50mA. Can be used to power low-current external sensors. Always powered.
3	Vin	Input for external 5V-to-7V DC power supply
4	Vdd (HI)	+3.3V rail from REG2. Can supply up to about 250mA, provided either USB power or external power is applied. Used to supply 'power hungry' sensors.

the microcontroller is in sleep mode), while the data output line from the memory card is also pulled high by a 33kΩ resistor.

Two oscillators

The microcontroller uses two oscillators – primary and secondary. The primary oscillator uses a 20MHz crystal (X1) to provide the main system clock. The oscillator's output is divided by five and multiplied by 12 (using an internal PLL stage) to derive the 48MHz clock, which is used by the USB peripheral (USB full-speed device, 12Mbps) and the core.

The core runs at 12 MIPS (million instructions per second), which is its highest rated speed.

The firmware implements a full-speed (12Mbps) USB device and the D+ and D– data outputs (pins 16 and 15) connect to a USB Type-B socket (CON2). This can be connected to a PC using a standard USB cable. A USB driver is required and we describe how this is installed in Part 2. (Note: the *USB Data Logger* has its own VID (Vendor ID) and PID (Product ID) pair, sub-licensed by Microchip).

The secondary oscillator uses a 32.768kHz watch crystal (X2) and two 12pF ceramic loading capacitors. This oscillator is almost always powered (even when the microcontroller is sleeping) and is used for timekeeping by the real-time clock/calendar (RTCC) peripheral inside IC1. This operates without firmware intervention to provide accurate timekeeping.

There are no switches to set the time and date. Instead, the time and date are automatically synchronised with the PC when the logger is connected to a USB port and the host program is launched.

Battery protection

The secondary oscillator is only switched off when the *USB Data Logger* goes into 'deep sleep' mode. This happens only if the firmware detects that the battery is critically low. In that case, IC1's core is shut down and goes into a deep-sleep mode to prevent the cells from discharging any further (which could damage them).

In addition, in this special sleep mode, the contents of the SRAM are lost and the timekeeping fails (to prevent battery drain).

The PC board fits neatly into a plastic instrument case. The full assembly details will be in Part 2 next month.

Once it has entered deep-sleep mode, the *USB Data Logger* will require a reset to resume normal operation. The way to do this is explained in next month's article.

Note that during normal operation, the microcontroller spends most of its time sleeping (thus reducing the power consumption) until the next logging event occurs. This sleep mode is different from the deep-sleep mode described above, however. While sleeping, the RTCC still operates, to maintain accurate timekeeping.

Sensing the supply voltage

During operation, IC1 monitors the supply voltage applied to boost regulator REG1. This is done by also applying this voltage to an ADC input, in this case AN4 at pin 7. As shown on Fig.1, the supply voltage is fed to AN4 of IC1 via a voltage divider consisting of two 4.7kΩ resistors. IC1 then converts the divided analogue voltage on its AN4 input to a 12-bit number.

When the logger is powered using two AAA cells, the supply voltage to REG1 will be about 2.7V at most (the maximum cell voltage is around 1.4V per cell and there is a Schottky diode in series with the positive battery terminal). On the other hand, if external power is applied to REG2, the voltage applied to REG1 will be close to 3V (the output of REG2 is at 3.3V and Schottky diode D1 is in series with its output).

A 100nF monolithic capacitor bypasses the divided voltage applied to AN4. This will be 1.35V maximum for a battery, and about 1.5V if external power is applied.

In operation, the microcontroller checks the supply voltage on a regular basis. If the cells are 'dangerously' low in voltage (indicating they have been discharged too much), the microcontroller goes into deep-sleep mode.

Power supply options

The entire circuit of the *USB Data Logger* is powered from the 3.3V rail. This includes the microcontroller (IC1) and the memory card. However, while the microcontroller itself is powered by a 3.3V rail, its core runs from a 2.5V rail and this is derived using an internal low drop-out regulator. A 10µF tantalum capacitor on pin 6 (VddCore/Vcap) decouples this 2.5V rail.

When running from a battery, the +3.3V rail is regulated using REG1, a TPS61097-33 low-power synchronous boost regulator IC (made by Texas Instruments). This switch-mode IC can convert an input voltage of between 0.9V and 3.3V into a regulated +3.3V rail and is capable of supplying up to 100mA.

Only three external components are required for REG1 – a 47µH inductor

Parts List For USB Data Logger

1 PC board, code 878 (double-sided), available from the *EPE PCB Service*, size 60mm × 78mm
1 plastic instrument case (Altronics H-0342 or H-0343)
1 SPDT sub-mini toggle switch (S1)
1 sub-mini momentary pushbutton switch (S2)
1 28-pin 0.3-inch IC socket (or 2 × 14-pin IC sockets)
1 20MHz crystal (X1)
1 32.768kHz crystal (X2)
1 USB Type-B socket, vertical PC-mount (Tyco Electronics Amphenol 5787834-1) (CON2)
1 AAA ×2 batteryholder (Jaycar PH-9226)
2 AAA 900mAh NiMH cells or 1 × 2-pack AAA 950mAh NiMH cells
1 memory card socket (Altronics P5722) (CON1)
1 8-way horizontal PC-mount 5.08mm pluggable terminal block header (Jaycar HM-3108)
1 8-way screw terminal socket (Jaycar HM-3128)
1 4-way horizontal PC-mount 5.08mm pluggable terminal block header (Jaycar HM-3104) (CON3)
1 4-way screw terminal socket (Jaycar HM-3124)

Semiconductors
1 PIC18F27J53-I/SP programmed microcontroller (IC1) – from **www.microchipdirect.com**
1 2N7000 MOSFET (Q1)
1 TPS61097-33DBVT boost regulator (REG1)
1 LM3940-3.3 regulator (REG2)
4 1N5819 diodes (D1 to D4)
1 1N4004 diode (D5)
1 3mm blue LED (LED1) (Jaycar ZD-0130)

Inductors
1 47µH choke (Jaycar LF-1100)

Capacitors
1 220µF low ESR 10V
1 47µF low ESR 63V
2 22µF tantalum
2 10µF tantalum
1 4.7µF tantalum
4 100nF monolithic
2 10nF monolithic
1 10nF greencap
2 33pF ceramic
2 12pF ceramic

Resistors (1%, 0.25W)
1 330kΩ
3 33kΩ
2 15kΩ
2 1kΩ
3 470Ω
2 10Ω
10 4.7kΩ

(L1), a 22µF tantalum bypass capacitor at the input and a 220µF low-ESR filter capacitor at the output. The regulator itself comes in an SOT-23 5-pin SMD (surface-mount device) package. However, it's quite easy to solder in by hand.

This switch-mode regulator has much better efficiency than a linear regulator and it allows the circuit to be powered from just two AAA cells.

This has four main advantages. First, cells are expensive, so using two rather than three decreases the cost. Second, using two AAA cells allows them to be trickle charged from a 3.3V rail since their voltage will not exceed about 2.8V when fully charged. Third, this allows us to use a standard double-cell holder. Fourth, it helps keep the unit small and light.

As mentioned previously, power can be supplied in three ways: (1) from two AAA cells; (2) from a PC via USB port CON2 (5V); or (3) from an external 5V-to-7V DC supply connected to pins 2 and 4 of CON3 (see Table 2). Switch S1 selects between either the USB power source or the external 5V-to-7V source; either of these sources can recharge the battery (if rechargeable cells are used).

Regulator REG2 (LM3940IT-3.3) is used to reduce the USB or external supply voltage to 3.3V. This is a linear low dropout 3.3V regulator which can operate from an input voltage as low as 4.5V. Its output is fed via Schottky diode D1 to the input of the switch-mode regulator (REG1).

A 10µF tantalum capacitor decouples the input to REG2, while a 47µF low-ESR (equivalent series resistance) aluminium electrolytic capacitor is installed across its output, to ensure stability. Don't be tempted to use a common electrolytic here – it **must** be a low-ESR type. The 1kΩ resistor to ground is there to provide a minimal load, while diode D4 provides reverse polarity protection when using an external supply.

Note that the input voltage at CON3 must be strictly between 5V and 7V DC (REG2 has a maximum input voltage rating of 7.5V). As such, you can use a 6V SLA (sealed lead-acid) battery or, if mains power is available, a regulated 6V DC plugpack.

If you want to use the data logger in your car (and don't want to use a battery), you can power it via a USB charger that plugs into your car's cigarette lighter socket and provides a regulated 5V.

Battery charging

The two rechargeable AAA cells provide power to the boost regulator (REG1) via Schottky diode D2. These will typically be rated at 900 to 950mAh, and are trickle charged from the 3.3V output of REG2 via Schottky diode D1 and a 10Ω resistor whenever USB or external power is connected.

The value of this resistor is chosen so that the charging current is around 0.05C (where C is the capacity of the battery). This amount is considered safe for indefinite charging and fully charging a battery in this way can take up to 15 hours (you can recharge the cells more quickly by removing them and placing them in an external charger if necessary).

For 900mAh cells, a charge rate of 0.05C means a charging current of 900 × 0.05 = 45mA. From there, it's easy to calculate the required resistor value. Assuming that the voltage drop across D1 is 0.3V, and that the average cell voltage is 1.25V, then the resistor value will be is (3 – 2.5)/0.045

= 11.1Ω. A 10Ω resistor is the nearest preferred value.

Diode D2 is reverse biased during charging and only becomes forward biased when USB or external power is removed. **Note that if you are using non-rechargeable, alkaline cells, together with an external power source, the 10Ω resistor must be omitted to prevent charging.** In this case, D2 provides reverse polarity protection against a reversed battery connection.

The *USB Data Logger* can run for long periods on just two AAA cells – typically two to three weeks, depending on the logging frequency. However, for very long-term logging without an external power supply, a 6V SLA battery rated at 12Ah will be required.

Pushbutton switch

Now let's consider the operation of pushbutton switch S2. As shown, this momentary SPDT switch is wired in parallel with the lower 4.7kΩ resistor in the divider. Pressing this switch pulls IC1's AN4 pin to GND, and this is detected by the microcontroller, which then takes the appropriate action.

Basically, the firmware uses the output of an internal comparator to sense when S2 is pressed. The AN4 pin is also connected to the inverting input of an internal comparator, while the non-inverting input is connected to an internal voltage reference.

This voltage reference can be controlled by the firmware and is derived from IC1's supply voltage using an internal resistor ladder network. In this case, the threshold is set at around 0.4V by the firmware, so any voltage below this at the AN4 input switches the output of the comparator high.

Since there is a 2:1 voltage divider on this input, this means that the comparator output is low, provided S2 is not pressed and the voltage at the input of REG1 is above around 0.8V. This should always be the case when the circuit is being powered, so the comparator output is normally low.

The comparator module is configured to generate an interrupt when its output goes from low to high. This occurs when S2 is pressed and starts a timer that measures how long S2 is held down.

The *USB Data Logger* recognises both a short press (less than 1s) and a long press (more than 1.5s). Once the key press is registered, the timer is shut down (to save power) and the firmware rearms the comparator interrupt after a hold-off delay.

In operation, long presses of S2 are used to start and stop the data logging. The short press is used to flash LED1 (blue) to provide operational feedback to the user. This LED is driven by the RC6 pin of IC1 as described previously, with a 470Ω resistor providing current limiting. We will describe its operation in more detail in Part 2 next month.

Scripting Language

Finally, we've written a custom scripting language so that the *USB Data Logger* can be configured for use with a wide range of digital sensors. This also involves the use of a Windows-based host program that can parse this scripting language and compile it into 'machine code'. This is then programmed into the USB data logger's non-volatile memory (ie, into a file on the memory card).

The reason for this scripting language is to allow a wide range of digital sensors to be used with the data logger. Rather than designing it to work with a select few sensors, with the scripting language you can configure it to suit whichever sensor you would like to use, as long as it operates using one of the supported protocols (I^{2}C or Dallas One Wire).

Having written a script to suit your sensor, the resulting code is then executed by the microcontroller, allowing it to communicate with that sensor and read its output.

Next month

That's all for this month. Next month, we'll give the assembly details and describe how it's used.

TechnoTalk

Something for everyone

Mark Nelson

With a revival of vintage computer technology, talking cars and Tandy catalogue nostalgia, Mark really has something for all tastes this month.

WHICH was the first functional computer of the modern computing era? Put your hand down if you thought it was the *Colossus* computer that helped break enemy codes at Bletchley Park. No, the honour goes to the machines invented in Germany by Konrad Zuse, who already in 1936 patented the world's first program-controlled computer. It used relays, not valves, but contained all the basic ingredients of modern machines, using the binary system and today's standard separation of storage and control.

Then in 1941, two years before *Colossus*, he completed *Z3*, the world's first fully functional programmable computer (details at **http://en.wikipedia.org/wiki/Z3_(computer)**). In 1945 he completed the *Z4*, the world's first commercial digital computer and again employing relays.

Although Zuse had wanted to use electronic switches, he was forced to make do with relays because the German government considered this enhancement not critical to the completion of the war, and indeed his machine functioned quite adequately with relays. But why on earth have I brought up this subject?

Back to the future

Simply because relays in computing are back. The NEMIAC project (Nano-Electro-Mechanical Integration And Computation) has the goal of building the world's first ever miniaturised, electro-mechanical, relay-based processor. A consortium led by IBM has been awarded £1.95 million by the European Commission to investigate nano-electro-mechanical relay-based computing for ultra-low power computing applications. With the world facing an energy crisis, there are obvious incentives to reduce the power consumption of computers.

Unfortunately, the fixed minimum power requirements of transistors limit their scope in ultra-low power applications. In addition, as transistors have been miniaturised, leakage power consumption is becoming as large as active power consumption. This becomes an issue of serious concern for emerging applications such as wireless communications and mobile computing.

On the other hand, nano-electro-mechanical (NEM) relays have the advantage of essentially zero 'off' current, promising significant improvements in energy efficiency. They offer the opportunity of 3-D integration with CMOS logic, having no performance penalty compared with solid-state and higher radiation resistance than CMOS. However, issues such as reliability, speed and miniaturisation need to be investigated in detail, hence this experimental project.

Making cars talk

'What's yours called?' The TV commercial for the Renault 5 car revealed that people christen their cars rather like the way that folk name their pets or children. And Basil Fawlty was probably not the only person who shouted at his car.

Across the Atlantic, they have upped the game and are now getting cars to talk. But this is no gimmick, as the technology is expected to help drivers avoid or reduce the severity of four out of five unimpaired vehicle crashes.

In a year-long trial that began in August, nearly 3,000 cars, trucks and buses have been equipped with 'connected' Wi-Fi technology to enable vehicles and infrastructure to 'talk' to each other in real time to help avoid crashes and improve traffic flow. Connected vehicles could also 'talk' to traffic signals, work zones, toll booths, school zones, and other types of infrastructure.

The experiment is taking place in Ann Arbor, Michigan, and is sponsored by the US Department of Transportation and is the largest road test to date of connected vehicle crash avoidance technology. The test cars, trucks and buses, most of which have been supplied by volunteer participants, are equipped with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication devices that will gather extensive data about system operability and its effectiveness at reducing crashes.

Cutting edge

To accomplish this, equipped vehicles send electronic data messages, receive messages from other equipped vehicles, and translate the data into a warning to the driver during specific hazardous traffic scenarios. Such hazards include an impending collision at a blind intersection, a vehicle changing lanes in another vehicle's blind spot, or a rear collision with a vehicle stopped ahead, among others.

That's the theory, but only real-world testing can prove its ultimate practicality, as National Highway Traffic Safety Administration Administrator David Strickland concedes. 'Vehicle-to-vehicle communication has the potential to be the ultimate game-changer in roadway safety – but we need to understand how to apply the technology in an effective way in the real world.'

A decision will be taken next year whether to proceed further with connected vehicle technology and possible legislation. You can read more at:

http://www.safercar.gov/ConnectedVehicles/pages/v2v.html.

Nostalgia corner

Do you remember the time when every town of a certain size had a Tandy shop, where you could nip round at 5.15pm on a Saturday and pick up a blister pack of 10kΩ resistors when you had run out? And show your free battery card, valid for one battery of your choice that month? I do, and it was not really all that long ago. I always asked for a D-cell, as I needed these to feed the unfeasibly long torches that they gave away occasionally.

If you feel any nostalgia, you might be pleased to know that some dedicated soul has spent a lot of time creating a website where you can pore over old Tandy catalogues and see those of Tandy's American chain, Radio Shack. The site includes a good history of Radio Shack, its affiliated companies and the firms that were taken over.

There is a forum for those who enjoy discussing the old products, also links to websites devoted to similar subjects. The website can be found at: **http://www.radioshackcatalogs.com/catalog_directory.html**

If you know of other sites like this, why not share the news with us?

Crystal-free 8-bit USB PIC® microcontrollers cut system costs and power consumption

0.25% clock accuracy enables USB connectivity, eliminating the need for external crystal

Microchip's lowest-cost and smallest-form-factor USB microcontrollers (MCUs), feature pin counts of 14 to 100 pins and are the first 8-bit MCUs to integrate LCD control, battery-backed RTCC, and USB on a single chip.

Microchip's latest USB PIC® MCUs feature internal clock sources with 0.25% clock accuracy to enable USB connectivity with no external crystal. They are also the first USB MCUs to combine pin-counts ranging from 14 to 100, with high peripheral integration and up to 128 KB of Flash. The eXtreme Low Power (XLP) technology also keeps power consumption down to 35 µA/MHz in active mode and 20 nA in sleep mode.

Lowest-cost and smallest-form-factor

The PIC16F145X MCUs give you USB connectivity and capacitive touch sensing, in addition to a wide range of integrated peripherals with footprints down to 4x4 mm.

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With an integrated Charge Time Measurement Unit (CTMU) and 1.8 V to 5 V operation, PIC18F2X/4XK50 MCUs are pin-compatible with legacy PIC18 MCUs, giving an easy migration to higher-performance.

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The PIC18F97J94 family gives you USB connectivity with LCD control, and a battery-backed real-time clock calendar (RTCC), all on a single 8-bit PIC® microcontroller.

GET STARTED IN 3 EASY STEPS:

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How to use the software. . .

DIGITAL LIGHTING CONTROLLER

Part 3 – by Nicholas Vinen

Christmas is just about here! Have you got your *Digital Lighting Controller* ready yet? In the first two articles we explained how it works and how to build it. This third article explains how to use the software – primarily the Windows-based sequencing program.

AS IT turns out, the majority of the time spent developing this project involved writing software – both the firmware and the sequencing utility. We only had space for a quick rundown of the software functions last month. Here is a more detailed explanation.

Audio conversion

As previously stated, the *Digital Lighting Controller* supports audio files in the WAV format, with 16 bits per sample, mono or stereo, in one of the supported sample rates (11.025kHz, 12kHz, 22.05kHz, 24kHz, 32kHz, 44.1kHz or 48kHz).

If you have an MP3 file (or other format) that you want to play or sequence using this device, you can use third-party software to convert it to WAV. This is also necessary if you want to use a WAV which contains compressed data (eg, μLaw or aLaw). There are many pieces of software capable of doing this.

The best is probably Audacity (http://audacity.sourceforge.net/). It is available for Windows, Mac OS X and Linux/Unix, and can be downloaded and used at no charge. All you need to do is open the audio file and then use the File->Export command to save it as a WAV.

This WAV file can then be loaded into the sequencing software. Note that it only handles simple WAV files (one chunk, etc). This is because it uses the same WAV routines as the Master unit does; so if you can open the file in the Windows software then it should work on the Master unit too. Even so, it doesn't hurt to check that the Master unit will play the WAV before you begin sequencing it.

Operation and additional features

Sequences can be created with or without audio. Sequences with audio have a **.lsq** file extension, those without have a **.lsn** extension.

The master unit scans the memory card for any files with a **.wav** or **.lsn** extension. WAV files are played with or without an accompanying **.lsq** lighting sequence. If there is no sequence, the lights are all switched off as the audio plays.

If an **.lsn** file is encountered instead, the audio output plays silence while the lighting sequence is displayed. In either case, after the sequence is finished, it moves on to the next file (unless you use the single file playback buttons on the remote control).

Since the last article was published, we added a 'mute' command, which can be triggered from either compatible remote control. It immediately sets the audio volume to zero and is cancelled by pressing mute again, changing the volume or else pressing play. It can be re-mapped to other infrared codes, just like the other remote control commands.

Note that a sample configuration file, showing all the main options, will be included with the HEX file and source code downloads.

Limitations

Because the sequences are stored compressed (reducing file size and memory card I/O), there is one minor restriction. Light ramps (when the brightness slowly fades up or down over time) have a minimum and maximum time period.

The possible range is about 0.016 to 8.2 seconds. It's unlikely you will need to go outside this range, and if you

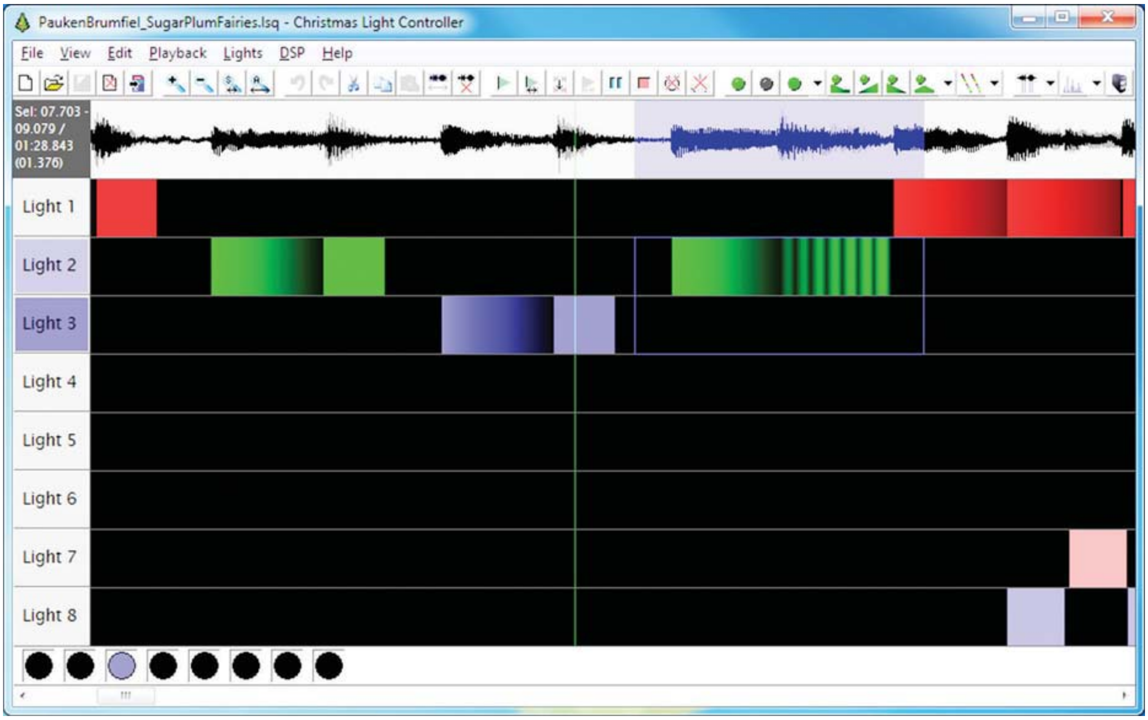


Fig.1: the main window, showing the WAV audio data at the top and the sequence below. The blue rectangle shows the current selection, while the green line is the playback cursor. The simulated light state is shown at the bottom. The main sequence display, in the middle, represents the brightness of each light over time with strips of colour. Note that some of the toolbar buttons are disabled. If you move the mouse cursor over them, you'll find out why.

do, the software will automatically adapt. For long ramps, it will substitute a series of evenly spaced 'set brightness' commands to give a similar effect. Still, it is a good idea to avoid very short or long ramps because they can complicate further sequence manipulation.

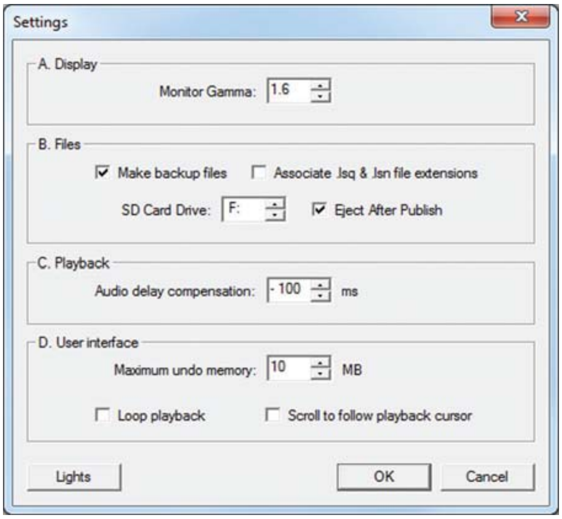


Fig.2: the settings dialogue, which provides a few options for tweaking the behaviour of the program. Most of the settings only need to be changed once.

Sequencing software

To install the Windows sequencing software, simply download and run the executable file. It will ask you a few questions (such as, where to put the files) but most users can ignore the questions (leaving the options at their defaults) and just click the 'Next' button until the installation is complete.

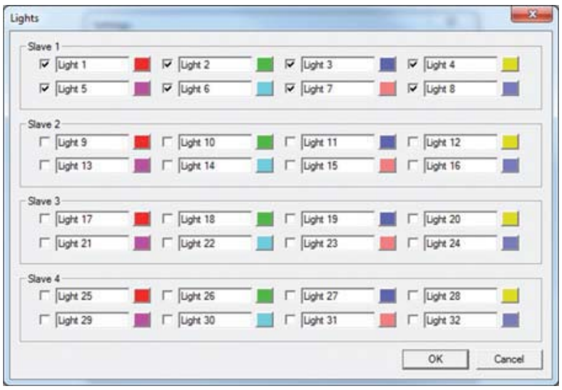


Fig.3: the lights dialogue, accessible via settings, which allows you to name each light channel and select the colour in which it will be displayed.

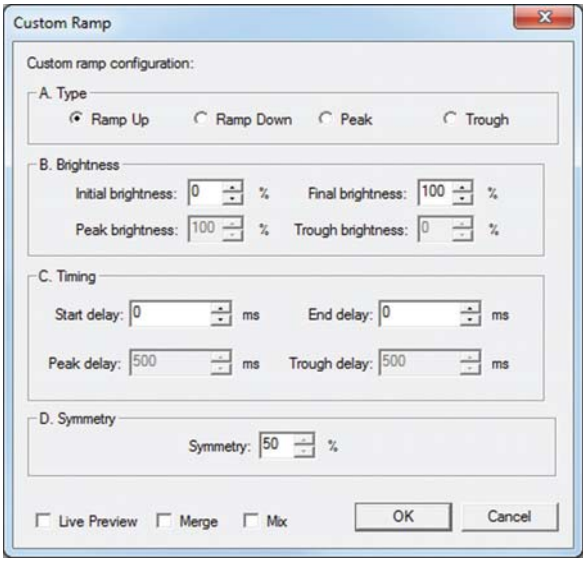


Fig.4: the Custom Ramp dialog allows you to create light ramps with a specific profile. Once a profile has been set up, it can be repeated many times on different channels at different times.

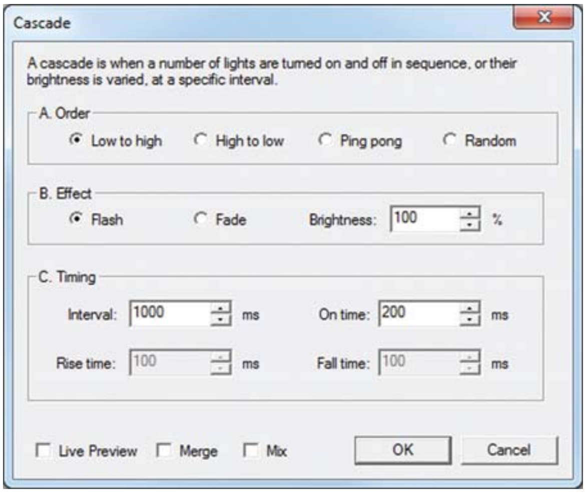


Fig.5: with the Cascade dialog you can create a pattern of lights across multiple channels. The lights flash in the specified pattern at the selected interval.

The first time you run the sequencing software, it is a good idea to go to the Settings screen (Edit→Settings) and adjust the options.

The most important is the audio delay. To set it, select a WAV file which has an obvious beat and then create a new sequence for it. Use the Play command (on the toolbar or in the menu) to play the file and watch the playback cursor (a green vertical line) as it moves across the display.

The beats should be visible as spikes in the WAV display at the top of the window. As the playback cursor reaches each spike, you should hear the beat simultaneously. If the playback cursor reaches the spike before the beat sounds, increase the delay. If the beat sounds before the playback cursor reaches the spike, decrease it. The possible range is ±1000ms (±one second). Repeat until it is correct.

The rest of the settings are explained in Table 1 at right. Having set them to your satisfaction, you are ready to create sequences. The rest of this article is dedicated to explaining the various controls, commands and options which you can use in choreographing your light display to the music.

Mouse controls

The mouse wheel zooms in or out on the sequence, centred on the portion under the mouse cursor. Rolling it up zooms in, while rolling it down zooms out. Note that this is true even while you are dragging a selection (see below).

Right clicking in the WAV display (at the top) or sequence display (below it) re-centres the display on that location. Right-dragging (ie, right-clicking and holding) in either area pans the display left or right. Panning can also be accomplished using the scroll bar, at the bottom of the window.

The mouse is used to define the selection initially and can also be used to adjust it. The selection is a portion of the sequence, outlined in blue. Most commands which manipulate the sequence only change the portion within the selection.

Table 1 – Settings

Monitor gamma	Used to display light brightness accurately. The default is 1.6, common values are 1.6 to 2.2.
Make backup files	If on (the default), each time you save over a sequence, the old file is kept with a different extension (maximum of ten backups).
Associate file extensions	If on (defaults to off), sequence files can be opened by double-clicking them in Windows Explorer.
SD card drive	This is auto-detected, but may need to be changed. The 'Publish' command copies the sequence to this drive.
Eject after publish	If on (the default), after publishing a sequence, the memory card is 'ejected' so that it can be immediately removed.
Audio delay compensation	Some sound drivers do not accurately report the playback position. If the audio synchronisation is off, adjust this value.
Maximum undo memory	Undo records are kept forever until they use up more than this much memory, when the oldest undo records are discarded.
Loop playback	Can also be set on the toolbar. If on, when playback reaches the end of the selected section, it starts again from the beginning.
Scroll to follow playback cursor	Can also be set on the toolbar. If on, when the playback cursor approaches the edge of the window, the display scrolls to follow it.
Lights	Selects which light channels are available and sets the associated names and colours. By default, the first eight are enabled.

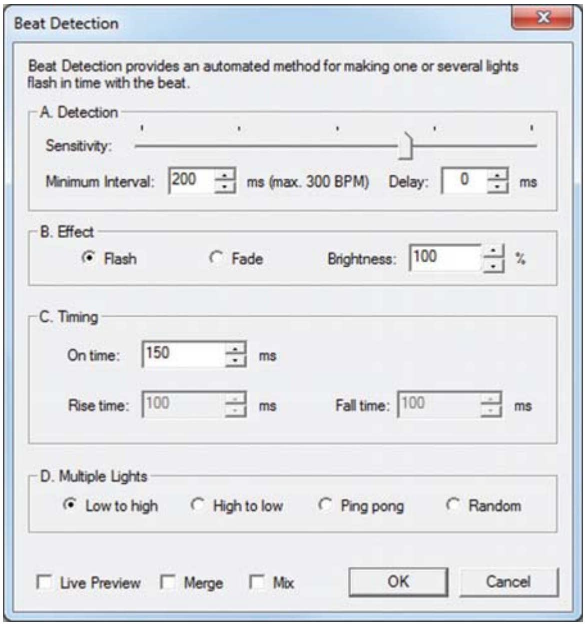


Fig.6: Beat Detection provides an automated hueristic for detecting beats in the music and causing lights to flash in time with them. It operates similarly to Cascade, but the flash times are determined by the music, rather than a simple interval.

To make a selection, move the mouse into either the WAV display or sequence display and hold the left button down. You can then 'drag out' an area to select it.

If you click the button rather than dragging the mouse, then this will select a single time point in the sequence. In this case, the 'Play Selection' command will play from that point until the end of the sequence, and the 'Paste' command will paste the copied data beginning at that point.

When dragging a selection, you can also move the mouse vertically to select one or more light channels simultaneously.

Once a selection has been made, you can drag the edges, changing the time span or the range of light channels selected. A double-arrow cursor indicates when the mouse is in the right location to change the selection.

Table 2 – Custom Ramp options

Type	Ramp Up increases brightness over time, Ramp down decreases it. Peak ramps up and then down, while Trough ramps down and then up.
Brightness	Defines the brightness at the salient points for the given ramp type.
Timing	Normally the ramp is stretched to fill the selection. Start and End Delay allow for padding. Peak/Trough delay, if set, creates a brightness plateau in those modes.
Symmetry	Available in Peak and Trough modes. The up and down ramps take the same time with 50% symmetry, while other values emphasise one or the other.

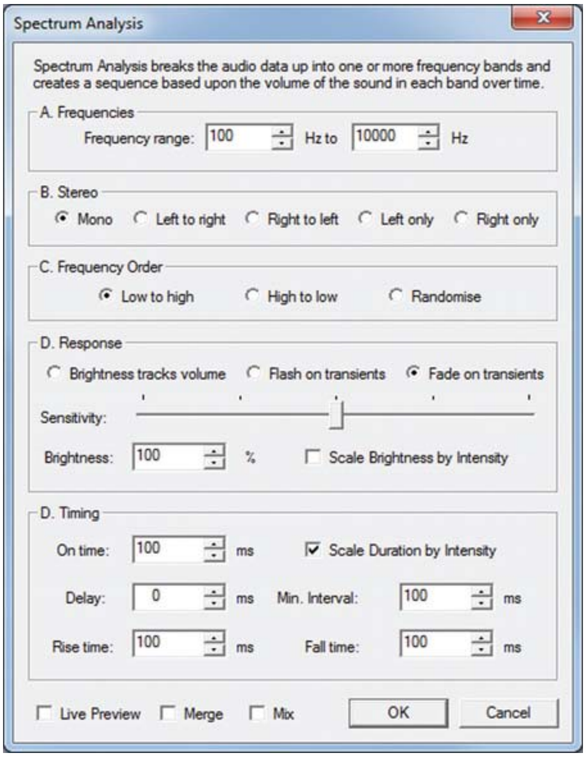


Fig.7: Spectrum Analysis operates like Beat Detection, but it breaks the audio up into multiple frequency bands and controls each lighting channel based on the audio within the separate bands.

While using the mouse to create or adjust a selection, if you move the mouse cursor off the left or right edge of the sequence area, the display will automatically scroll in that direction.

The light channel selection can be altered without affecting the selection time span by clicking on the light names at the left side of the window. Holding down shift or control while

Table 3 – Cascade options

Order	The order in which channels are flashed. 'Low to High' starts with the first selected channel and then moves to higher channels, wrapping back around to the first. 'High to Low' is the opposite. 'Ping-pong' alternates between the previous two. 'Random' creates an arbitrary pattern.
Effect	When Flash is selected, the light simply turns on for the selected On Time. With Fade, the beginning and end are ramped, according to the Rise time and Fall time settings.
Brightness	The peak brightness of each light flash.
Interval	The time between flashes being triggered on subsequent channels. This can be shorter than the On time if desired and the flashes will overlap.

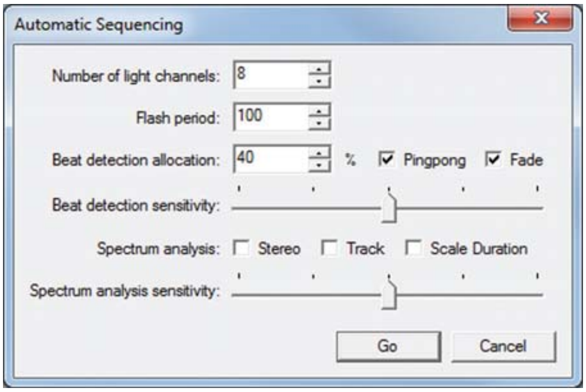


Fig.8: Automatic Sequencing is a feature which allows you to quickly and easily generate a sequence for a piece of music, based on beat detection and spectrum analysis. It can be further modified or used as-is.

clicking on the light names allows you to select a range or group of them. This allows you to manipulate a number of channels at once; eg, to create a Cascade (more on this later).

It is also possible to adjust the amount of space available for WAV data display at the top of the screen. Move the mouse over the line dividing the WAV and sequence area and drag it up or down. You can use the same technique to adjust the left/right split between the light names and the sequence data.

Keyboard controls

In addition to the keyboard shortcuts (shown in the menus), there are some extra keyboard controls which perform basic functions, such as changing the selection.

The arrow keys, in combination with shift and control, allow you to move the current selection or scroll the display. The left and right arrows by themselves move the selection left and right and if the shift key is held down at the same time, it moves in larger increments (x10). Moving the selection with the keyboard allows you easily make fine timing adjustments.

The up and down arrows also move the selection up and down, selecting a different set of light channels. If shift is held down at the same time, then rather than moving the selection, it is extended.

If the Control key is held down while pressing the left and right arrows, the display scrolls left or right. In this mode the shift key can also be used for larger increments.

Dialogs

While much of the sequencing work is done in the main program window, the software also includes a number of ‘dialogs’. These are windows which pop up when certain options are selected, allowing you to enter additional parameters.

The available dialogs are: *Settings*, *Lights*, *Custom Ramp*, *Cascade*, *Beat Detection*, *Spectrum Analysis* and *Automatic Sequencing*.

The first two are used to alter the behaviour of the program, while the others manipulate the sequence in some way. One thing they all have in common are the ‘OK’ and ‘Cancel’ buttons. Either button will close the dialog, but pressing ‘Cancel’ also discards any changes made since it was opened.

You can only have one dialog open at any time. For dialogs that manipulate the sequence, only the selected portion is affected, except in the case of Automatic Sequencing, which always operates on the whole file. Thus, most of these dialogs are unavailable while there is no selection.

Previews

Some options are common to several dialogs. If ‘Live Preview’ is turned on, then the selected operation is performed immediately, so that you can see what its result will be. If you then cancel the dialog, the changes are undone. If you adjust any of the dialog parameters, the preview will update to reflect the change.

Table 4 – Beat Detection options

Sensitivity	Determines the transient energy required to trigger a light flash.
Minimum interval	Once a beat has been detected, any transients are ignored for this period after it. The equivalent maximum BPM (beats per minute) are shown.
Delay	Each light flash is offset by this amount (±) from the detected transient. Most commonly used in ‘Fade’ mode to compensate for the initial ramp.
Effect, Timing, Multiple Lights	As with Cascade. The ‘Multiple Lights’ settings are only available if more than one light channel has been selected.

Table 5 – Spectrum Analysis options

Frequency range	The upper and lower ends of the frequency bands. This range is broken into enough logarithmic steps for the selected light channels.
Stereo	If ‘left to right’ or ‘right to left’ is selected then the light channels are divided in half, one set using left channel audio and the other right channel audio. Otherwise, the selected channel is used for all bands.
Frequency order	Determines the order in which the resulting bands are mapped on to the light channels.
Response	The Flash and Fade modes work similarly to Cascade. The Sensitivity control works similarly to Beat Detection. For ‘Brightness tracks volume’, instead of flashing, the brightness of each light channel varies continuously, tracking the audio level in each frequency band.
Scale brightness by intensity	In Flash/Fade mode, this causes the brightness to be modulated by the intensity of each transient.
Scale duration by intensity	In Flash/Fade mode, this causes the On Time and if appropriate, Rise and Fall times, to be modulated by the intensity of each transient.
Timing	As for Beat Detection.

COMMANDS	
The software supports many commands which are accessible via the menu or the toolbar. While most of them are self-explanatory, the following are worth elaborating.	
File->Publish Sequence	This copies the loaded sequence on to your memory card, along with the accompanying WAV file (if appropriate). The memory card drive letter is set automatically, but you should check the settings before using this feature and adjust it if necessary.
Edit->Paste Special	Normally, when you copy and then paste sequence data, the data is copied exactly. The only change normally made is when the selection into which it is being pasted is smaller than what was copied, in which case some of the data is omitted. However, the Paste Special menu provides five ways to paste data that also manipulate it in some way. If Paste Stretch is used, the duration of the data copied will be lengthened or shortened to fit the current selection, time-stretching it. Paste Mix and Paste Merge allow the sequence data in the copy buffer to be combined with the data within the current selection. In the case of 'Merge', the brightest light value will dominate at any given time. This is useful in a case where you want to leave the existing sequence as it is, but add new lighting commands on top. 'Mix' is similar, but the resulting brightness is the product of the existing and pasted brightnesses. This is especially useful with the Custom Ramp option, as it allows you to take a series of light flashes (or ramps, etc) and apply a ramp over the top, which modulates their brightness over time. This effect is shown within the selection in Fig.1.
Edit->Copy Buffer Storage	Normally, if you perform a 'Cut' or 'Copy' command, the contents of the copy buffer are replaced with the selected data and thus lost. Sometimes you need to be able to store multiple sequence sections in order to paste them later, in a different order. Copy Buffer Storage gives you nine additional holding locations. First, copy or cut the data in the normal manner, then store the contents of the copy buffer using this menu. The contents can be retrieved later and then pasted as usual.
Edit->Selection Storage	This menu allows you to store the location of the current selection so that you can recall it later. After making a selection, store it in one of the nine locations. It can then be restored any time. The stored selection includes both the light channels and time span.
Edit->Change Length	This is only available if you are editing a stand-alone sequence (ie, one without audio). In this case, you can change the length (ie, running time) at will. Note that if you reduce the length, any data past the end will be lost.
Playback->Set Playback Region	If you select a time span and then use this command, the selection becomes the new playback region, which is shown in red. It is then independent of the selection. The 'Play Region' command will then play that portion of the sequence. This is handy when you want to make a number of changes to a given section and play it back to check what you have done afterwards, without having to re-select the whole section each time.
Lights->Cancel Light Actions	All sequence commands in the selection are deleted. This means that during this period, the lights will remain in whatever state they were left just prior to it. To turn the lights off instead, use the 'Lights Off' command.
Lights->Set Light Brightness	This option sets the brightness of the selected lights, in the selected time period, to be a constant, between 0% and 100% of full brightness. The actual brightness is set using the dropdown arrow adjacent to this command in the toolbar.
Lights->Interpolated Ramp	This ramps the brightness of the selected lights smoothly from whatever brightness they are at the beginning of the selection to that at the end.
Lights->Ramp Up/Down	These commands take the brightness of the selected lights at the beginning of the selection and either ramp them up to maximum brightness or down to minimum brightness (off) over the selected period.
Lights->Custom Ramp/Cascade	See the section on dialogs.
DSP->Beat Detection/Spectrum Analysis/Automatic Sequencing	See the section on dialogs.

Table 6 – Automatic Sequencing options

Number of light channels	Defaults to the number of available channels. Use a lower number to leave some channels unaffected.
Flash period	Controls the flash duration
Beat detection allocation	The proportion of available channels to dedicate to the Beat Detection function.
Pingpong	Controls whether the Beat Detection uses 'Low to high' or 'Pingpong' order.
Fade	Controls whether the Beat Detection uses 'Flash' or 'Fade' mode.
Beat detection sensitivity	Allows the sensitivity to be adjusted over the most useful portion of the range.
Spectrum analysis	Stereo controls whether the Spectrum Analysis feature uses 'Left to right' or 'Mono' mode. Track selects either 'Brightness tracks volume' or 'Fade' mode. 'Scale Duration' selects either 'Scale Brightness' or 'Scale Duration' mode.
Spectrum analysis sensitivity	Allows the sensitivity to be adjusted over the most useful portion of the range.

Because the operation could be slow if the selection is large (eg, Spectrum Analysis), it is a good idea to zoom into a portion of the selection while using Live Preview. In this case, only the visible portion will be updated, speeding up the preview.

Once you click 'OK' then the operation will be performed over the entire selection.

Any operations which take more than about a quarter of a second will display a progress dialog. This is true whether it is a preview or the final operation which is being performed. When the progress dialog is open, it is possible to cancel the operation.

Note that it is possible to go to the main window and scroll/zoom while a dialog is open. If Live Preview is active, the preview will automatically re-calculate when the view is changed (if necessary). You can also change the selection while a dialog is open. If Live Preview is active then the preview will be changed to apply to the new selection.

Common options

The other two common dialog options are 'Merge' and 'Mix', which perform the same operations as described under the 'Paste Special' command.

When you click 'OK' in a dialog, the options that you have selected are remembered for next time you perform that same operation.

In addition, many of the dialogs are accessible via the toolbar as double-action buttons. Clicking the dropdown arrow alongside the button opens the dialog, while pressing the button itself immediately applies the associated operation.

This means that once you have the options set up the way you want and clicked 'OK', you can repeat the same operation on a different selection using the toolbar button, without having to go through the dialog.

Alternatively, you can click the dropdown arrow and adjust the parameters again.

Custom Ramp and Cascade

The Custom Ramp dialog allows you to create a smoothly changing brightness level for one or more lights over a given time period. See Table 2 for the possible options.

Note that as you change between the four different ramp types, the brightness values are shuffled around so that you don't have to make as many adjustments.

Cascade creates an effect where flashes occur across multiple light channels over time, with a constant period and duration for each flash. It is also possible to smooth the beginning and end of each flash with a brightness ramp.

See Table 3 for the available options. It is possible to select a single light channel for a Cascade, in which case the Order option is disabled, since it has no effect.

Beat Detection

Beat Detection provides a means to analyse the audio and attempt to discover the beat by looking for transients. Before searching for transients, a fourth-order notch filter is applied to the audio (400Hz to 4kHz) in order to eliminate vocals and other instruments which might otherwise fool the algorithm.

The sensitivity is critical and its operation is not always intuitive. It is a good idea to pick a small section of the audio file and try different sensitivity settings (using the Live Preview option) in order to detemine the setting which picks up the beats most reliably without much spurious triggering.

The best settings are usually between mid-scale and halfway to maximum.

Once the beats are detected, they are passed on to the Cascade routine, providing similar options for light triggering on each detected transient. The full set of options is explained in Table 4.

Spectrum Analysis

This is the most complicated of the sequencing dialogs. Spectrum Analysis is much like Beat Detection, but rather than using a notch filter, instead the frequency spectrum is broken up into a series of bands and a bandpass filter (fourth order) is applied to isolate each set of frequencies. As with Beat Detection, transients in the result trigger flashing lights.

Since each lighting channel operates on a separate band, the lights respond to different frequencies, creating a more interesting effect. See Table 5 for a summary of the options.

The final dialog, Automatic Sequencing, combines Beat Detection and Spectrum Analysis while presenting fewer options.

This makes it easy to create a quick sequence for an audio file. Simply click the icon, adjust the settings (or leave them at the defaults) and then click 'Go'.

There is no preview in this mode, but if you do not like the results you can undo the changes, adjust the parameters and try again.

For a description of the Automatic Sequencing options, see Table 6.

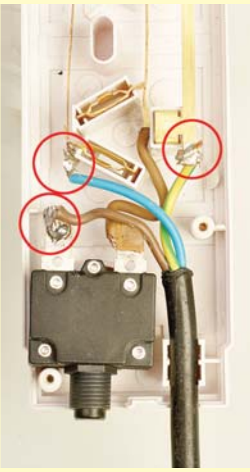
Connecting multiple lights without spending big $$$!

As you will recall from the first two parts, the *Digital Lighting Controller* has IEC mains output sockets, mainly because they will fit! However, practically all lights you can buy, especially Christmas lights, will be fitted with a standard 3-pin mains plug.

We recommended buying an IEC-to-3-pin-mains converter lead, such as that shown bottom left in the picture below. However, these are relatively expensive (£5 to £10 each approx.) so for eight channels it quickly adds up.

And what happens when (as you almost certainly will with Christmas lights) you want to plug in multiple lights into the same channel?

We have come up with a pretty cheap solution for both problems – and that is to use a standard 4-way mains power board (which you can buy anywhere these days for a few pounds) and change the 230V mains lead over to one fitted with an IEC plug (The board shown is Australian, but UK equivalents are widely available.)



Where do you get such a lead? Call us 'bower-birds' if you like, but every time we have thrown out an old CRT monitor, we have cut off the mains lead (back in the early days CRT monitors used to plug into the computer via an IEC socket). Ergo, our junk box had several lengths of mains leads fitted at one end with IEC plugs.

So for us, the only cost was buying some power boards, and you can often get a good deal on a pack of four or more.

Don't have spare IEC cables on hand?

If you don't have the luxury of a well-stocked junk box, the alternative is to use a powerboard as is but change the mains plug over to an IEC type (as shown at right in the photo below). It's not quite as cheap (these plugs usually sell for about £4 each) but at least you get multiple outlets via the powerboard.

Opening up the powerboard

Usually, powerboards are assembled with tamper-proof screws – so you're going to need a tamper-proof screwdriver to remove them. (What self-respecting hobbyist wouldn't have a set of tamper-proof bits in his/her toolbox?).

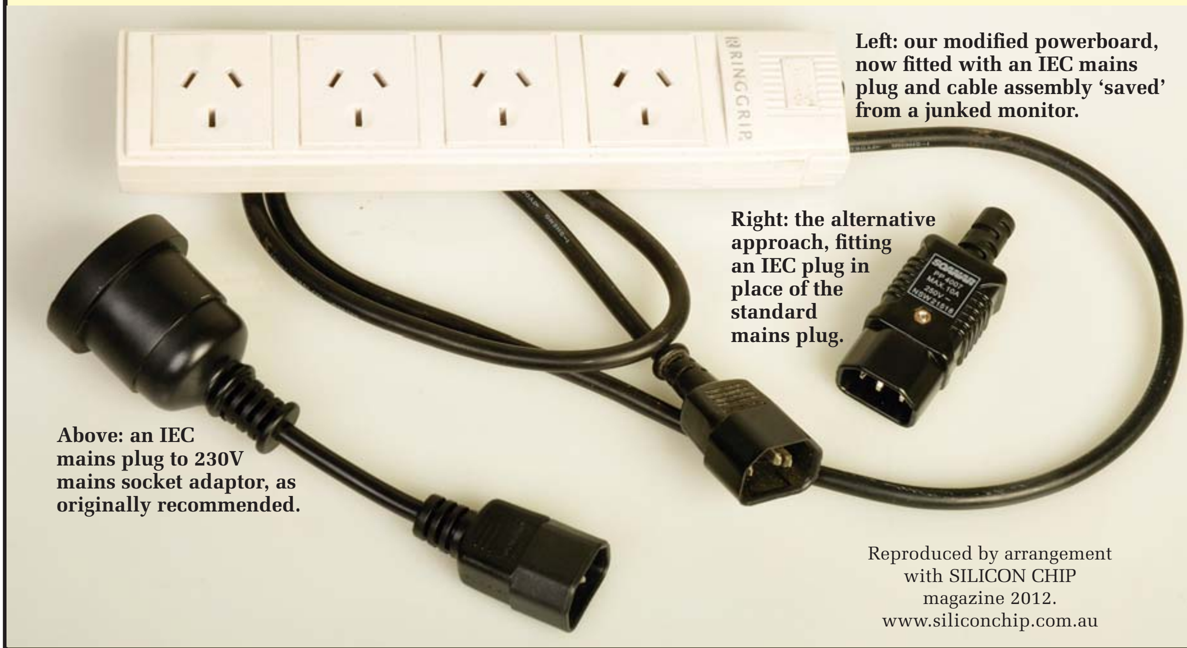
Most we found simply use a slotted screw with centre raised section, which requires a slotted blade bit. However, we've also found them with star, Torx and other bits. Sometimes they are rivetted or welded together, in which case you can't do this modification. Check your powerboard before buying!

Remove the screws with whatever bit it takes and the two halves of the powerboard should separate. There will almost certainly be an overload circuit breaker built in – leave the brown wire connecting this to the 'live' bus bar, but cut off the earth wire where it connects to the earth bus and similarly the neutral (blue) wire where it connects to the neutral bus.

Remove the live (brown) wire where it connects to the input of the circuit breaker.

Invariably, the wires are all welded, so they will have to be cut away. Replace the cable with your IEC-ended cable, cutting the brown, blue and green/yellow leads to the same length as those you removed.

Make sure the individual wires are mechanically secured to the bus bars (ie, wrap them around tightly) and then solder them in place. Replace the cover and you're done. ***EPE***



Left: our modified powerboard, now fitted with an IEC mains plug and cable assembly 'saved' from a junked monitor.

Right: the alternative approach, fitting an IEC plug in place of the standard mains plug.

Above: an IEC mains plug to 230V mains socket adaptor, as originally recommended.

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WITH INBUILT HEAT CONTROLLER

If you've ever tried to cut polystyrene or polyurethane materials using a saw, razor blade or knife, you'll know that the results are invariably less than satisfactory. If you are after a clean, precise cut, a hot-wire cutter is the answer. The hot wire actually melts the material and results in a very neat, very fine cut, without the thousands of bits of foam flakes you normally get.

By JOHN CLARKE

FOR modelling, hobby and furniture upholstery work, our *Hot-Wire Cutter* is a must-have.

No more material deformation, no more jagged edges and crooked cuts, no more beads of polystyrene broken off and flying about – and the cut is so much more accurate into the bargain.

But wait, there's more: the *Hot-Wire Cutter* includes a heat controller to allow the wire temperature to be adjusted to produce a clean cut regardless of the thickness or even the type of material being cut.

It suits a variety of low-melting-point 'thermoplastics' – but with polystyrene it really comes into its own.

There are two common forms of polystyrene – the beaded type, popular as packaging material, and as the 'beans' inside beanbags.

When all those beads of polystyrene are extruded into a block, we get the type of 'foam' we're so familiar with. Extruded polystyrene has an enormous variety of uses. It's widely found in consumer goods packaging, it's used in modelling, it forms the basis for surfboards and other floating aids, and is used as an insulator – sometimes on its own, but more often 'sandwiched' between two tougher materials, because on its own it's quite brittle.

Take a letter

Believe it or not, the letters in the photo above were actually cut (using our new *Hot-Wire Cutter*, of course!) from offcuts of 50mm-thick polystyrene foam used as part of the cladding on a home.

Polyurethane, at least in the form we are talking about, is often called 'foam rubber', though of course there is no rubber in it.

Its most common use is for padding in furniture and even car seats. It's also shaped into many products, such as bedding underlays. In its 'crumbled' (or crumbed) form it too is used extensively as a packaging material.

Both types of plastic have a relatively low melting point of around 170°C to 240°C, and both are delightfully easy to cut with a *Hot-Wire Cutter*.

Other types of plastic that could be cut with a *Hot-Wire Cutter* include PET (eg, soft drink bottles), ABS (eg, 'plastic' cases and parts) and clear or coloured acrylic or perspex.

We'll have more to say about cutting these different plastics later.

Hot-Wire Cutter design

Hot-Wire cutters are relatively simple and comprise a frame that supports a length of heated resistance wire, which is kept taut by some form of spring. The wire needs to be taut so that the cut is straight and the wire does not bend while cutting the material. Tensioning is also required to maintain wire rigidity, as the wire expands when heated.

A power source is required to provide the energy to heat up the wire. This can be sourced from a battery, or via a low voltage supply derived from the mains. Our tests show that

you need up to 100W per metre for cutting polystyrene and polyurethane.

Ideally, a means to adjust the power applied to the wire is available, so that the wire temperature is correct. If too high, it can cause melting or burning of the material and ultimately the melting (and eventual snapping) of the cutting wire. If too low, the material will not melt and therefore not cut, and the cutting wire will be strained.

The power is made adjustable to give the best cut for the type of material without too much curling at the cutting edge. The heat setting also sets the rate at which the material can be fed through the cutter. Again, if it is too low, the material needs to be pushed harder to cut and this too may cause the cutting wire to break.

Refinements to this cutter include a plinth and adjustable edge guide so that sliding along this straight edge can cut the material straight. Some cutters include automatic feed so that the cut is consistent along the length.

When feeding by hand, any hesitation in feeding the material will cause excess melting. Feed the material too fast and the wire will tend to bow. The bowing is caused by the wire's inability to melt the material at the rate that the material is fed and hence cutting is slowed or halted. The solution is to feed the material more slowly or to increase the power fed to the wire. It's wise to practise on pieces of scrap material before trusting your skill on real work.

Our cutter is a hand-fed unit suitable for hobbyists making models and general plastic cutting. The actual size of the cutter depends on the size of material that needs to be cut. For upholstery work, a cutter that has more than 450mm wire length may be required and with a similar throat size, so it has the ability to cut wide work. Modelling work may only require a short length of wire, say 150mm long.

Hot-Wire Cutter controller

OK, now all that is out of the way, let's see how to make a practical *Hot-Wire Cutter controller*. We'll look at the actual cutter shortly.

Ours is housed in a small box containing the circuitry, mounted on a single PC board. The only controls are a power switch and 'temperature' knob. These are located on the top of the box. A DC socket is for power in, while power out is via leads that pass through a cable gland. These leads connect to the 'hot' wire.

The temperature knob doesn't actually control the wire temperature as such, rather it works by controlling the rate at which power to the resistive wire is switched on and off, which in turn controls the average power applied.

This average power sets a constant temperature in the wire. At full setting for the *Hot-Wire Cutter* controller (fully clockwise), power is delivered continuously to the hot wire, providing the maximum power. As the control is wound anticlockwise, the percentage of time that the power is delivered to the hot wire is reduced. At the mid-point adjustment setting, for example, the controller applies power to the wire for half the time, and so power is 50%.

The controller can adjust the power from essentially fully off through to fully on, allowing a full range of heat adjustment for the *Hot-Wire Cutter*.

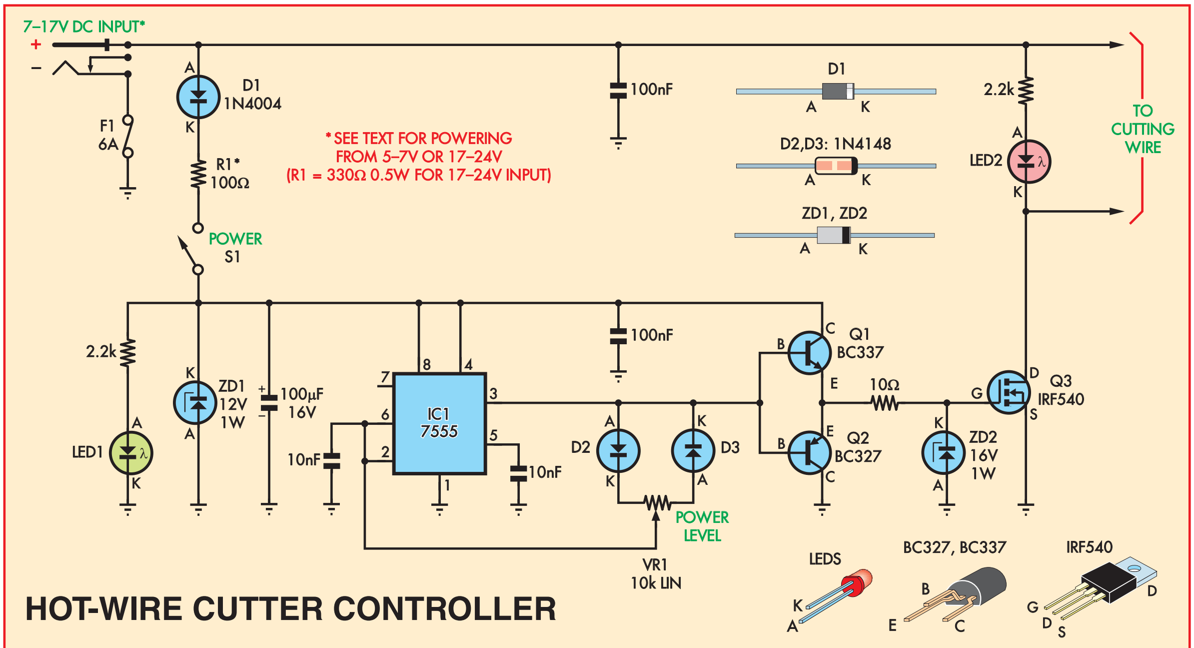


Fig. 1: the *Hot-Wire Cutter* controller sets the wire temperature by varying the on/off power ratio, switched by Q3

Circuit details

The full circuit diagram for the *Hot-Wire Cutter Controller* is shown in Fig.1. A CMOS version of a 555 timer (IC1) and a power MOSFET (Q3) plus a few extra components are used for power switching. Timer IC1 is arranged as an oscillator, with the 10nF capacitor at pin 2 and pin 6 charged and discharged via the pin 3 output through diodes D2 and D3, and Power Level potentiometer VR1.

With the 10nF capacitor discharged, pin 3 will be high at close to the supply voltage and the capacitor charges via diode D2 and the section of VR1 between the cathode (K) of D2 and the wiper (moving contact) of VR1. When the voltage reaches two-thirds of the supply voltage, this is detected by the threshold input at pin 6. The pin 3 output then goes low at close to 0V. Now the 10nF capacitor discharges via diode D3 and the section of VR1 between the anode (A) of D3 and the wiper of VR1.

The capacitor continues to discharge until its voltage reaches one third of the supply. This voltage is detected by the trigger input at pin 2. The pin 3 output then goes high and the charging of the capacitor restarts.

If potentiometer VR1 is set to midway, there is a similar resistance between the wiper and the cathode of D2 and the wiper and the anode of D3. The capacitor charges and discharges over a similar time, and so output pin 3 is high for about the same time it is low, providing a 50% duty cycle.

When VR1 is set so the wiper is fully toward the cathode of D2, the 10nF capacitor charges very quickly, directly via D2, and so the pin 3 output is only high for a brief period. The period during which the pin 3 output is low is much longer due to discharge via the full VR1 resistance.

In a similar way, when the wiper of VR1 is set fully toward the anode of D3, pin 3 is low for a short period as it discharges the capacitor directly via D3. Charging is via D2 and the full VR1 resistance.

Frequency of operation remains the same regardless of the position for VR1 because the frequency is the inverse of the total period for when pin 3 is both low and high. The total resistance of VR1 and the 10nF capacitor sets this period, which is about 69µs (0.693 ×10nF × 10kΩ) and frequency is the inverse of this, about 14kHz.

The output (pin 3) drives buffer transistors Q1 and Q2. When pin 3 is high, Q1 is switched on to drive the gate of MOSFET Q3 via the 10Ω resistor. When pin 3 goes low, Q2 switches on to discharge the gate of Q3 via the 10Ω resistor. The 16V Zener diode ZD2 prevents the gate going beyond the safe operating voltage for the MOSFET.

MOSFET Q3 drives the resistance wire between the positive supply and the drain (D). Indicator LED2 lights when Q3 is on and its brightness depends on the duty cycle of the switching. Full brightness is when the MOSFET is continuously switched on.

The power indicator LED1 lights to show when power to the circuit is connected via switch S1. Diode D1 provides reverse polarity protection, while resistor R1 limits current to the oscillator circuit, regulated to 12V by Zener diode ZD1. This conducts when the input supply is above 12.6V. The Zener is required to prevent IC1 being powered by more than its absolute maximum voltage of 15V for the LMC555CN.

The circuit as shown is designed for a supply between 7V and 17V, but it can be used with lower voltages down to 5V and up to 24V with some minor changes. *We do not recommend controlling over 5A.*

Other voltage operation

If you plan to operate the controller with a supply that is between 17V

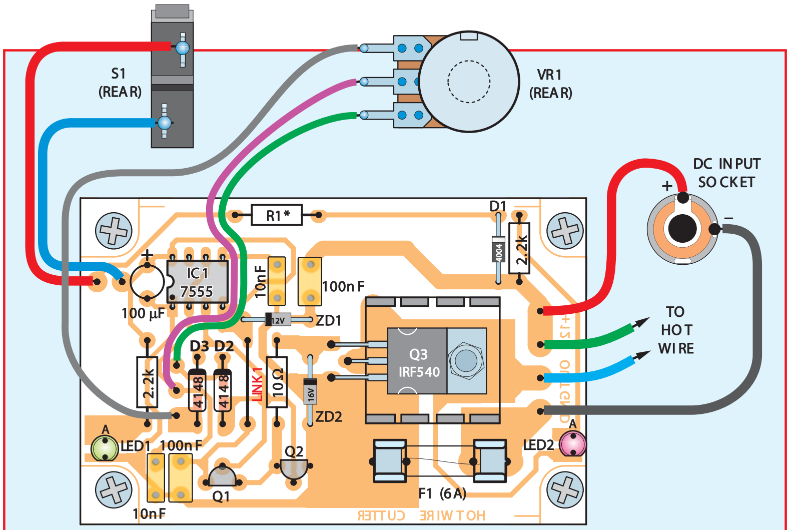
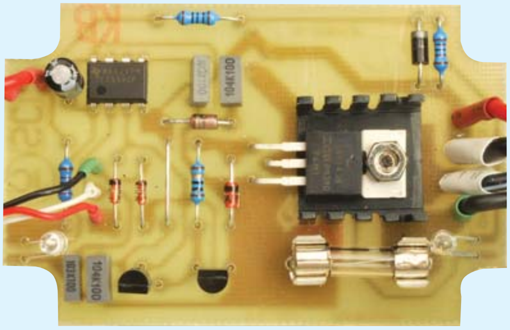


Fig.2: same-size component layout, with a matching photo below



and 24V, then resistor R1 should be changed from 100Ω to 330Ω 1/2W to reduce the power dissipation in the 12V Zener diode. No other changes are necessary.

Normally, we wouldn't recommend operating with voltages lower than 7V, but there might be situations where this is necessary. To do so, changes are necessary so that the gate drive to MOSFET Q3 is sufficient for the device to switch on fully. To allow this, Q3 is changed to a logic-level type – MOSFET IRL540N.

Also, replace diode D1 with a wire link and change Zener diodes ZD1 and ZD2 to 9V, 1W types. Note that reverse polarity protection without diode D1 relies on ZD1 conducting with reverse supply. R1 remains at 100Ω as shown, and current is limited to 64mA or less through the 100Ω resistor. This resistor should be 1/2W rated.

Construction

The *Hot-Wire Cutter* controller is constructed on a small PC board, measuring just 77mm × 50mm. This board is available from the *EPE PCB Service*, code 877.

The PC board is mounted so that the plastic case is actually upside-down – ie, the base of the case becomes the front panel and the lid is on the bottom. This means that switch S1 and potentiometer VR1 are mounted through the 'base' of the case.

The PC board mounts with the components facing the base of the case. The board is shaped so the corner pillars are cleared, so that the PC board sits on the internal side supports in the box. When the lid is in position, the PC board is held tightly in place.

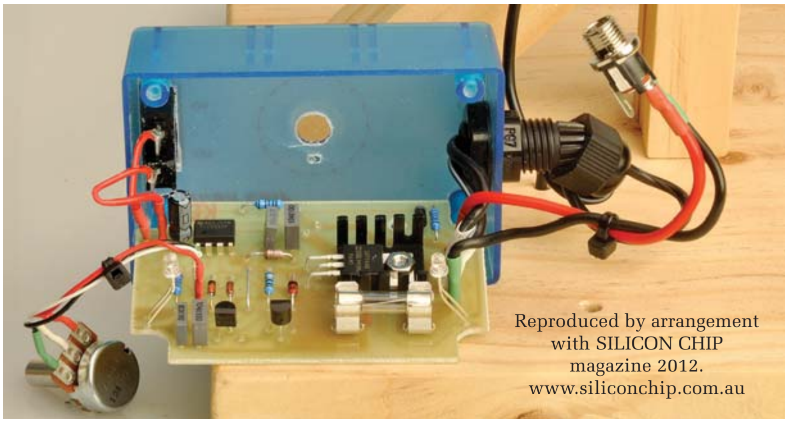
Board assembly

Begin construction by making sure the board fits into the case and then check the PC board for breaks in tracks or shorts between tracks and pads. Repair if necessary. Check the sizes of the holes are correct for each component to fit in position. The screw terminal holes are 1.25mm in diameter, compared to the 0.9mm holes for the ICs, resistors and diodes. Larger holes again are used for the fuse clips.

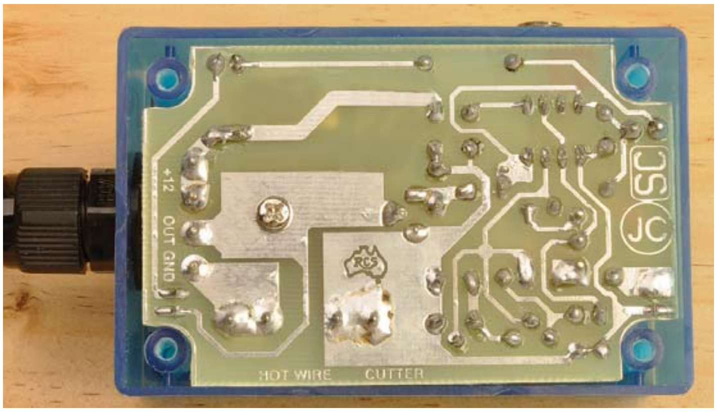
Assembly can begin by inserting the resistors and wire link. When inserting the resistors, use a digital multimeter to confirm each resistor value. The diodes can now be installed – these are, of course, all polarised, so they must be mounted with the orientation shown in Fig.2. Note that there are three different diode packages: take care!

MOSFET transistor Q3 mounts horizontally on its finned heatsink and both the transistor and heatsink are held in place with a 6mm M3 screw and nut. Bend the leads at right angles to suit the holes in the PC board and secure it to the heatsink and board with the screw and nut ***before*** soldering the leads in place.

PC solder stakes can be installed for the three terminals used for wiring to VR1 and for the power switch S1 and the DC socket and hot-wire connections. IC1 can be mounted on an 8-pin



Here's how it all looks just before the pot and DC socket are screwed into position and the board is pushed back into the case, ready for mounting



The completed PC board 'folds' down into the bottom of the case so that the case lid becomes the new base. Only two screws hold the lid on; the other two holes are used to secure the Controller to the *Hot-Wire Cutter* baseboard.

IC socket or directly onto the PC board. Make sure the socket and IC are installed with the correct orientation. Orientation is with the notch positioned as shown.

Transistors Q1, the BC337 and Q2, the BC327, can now be soldered in place.

If a clear or translucent box is used, the LEDs are mounted inside the box with their tops about 20mm above the PC board surface. If a non-see-through box is used, the LEDs must be mounted high enough – the top of the LED about 25mm above the PC board – for them to peek through the base of the box (which becomes the front panel). Take care with the LED orientation. The anode has the longer lead.

Capacitors can be mounted next, again ensuring the electrolytic types are oriented correctly.

Fuse clips for the fuse (F1) can be installed, noting that each clip has an end stop to prevent the fuse sliding out. These end stops are oriented to be at the *outside* of the fuse. Usually it is easier to clip the fuse in the fuse clips first, and then place the clips into the PC board. That way they will be oriented correctly.

Finishing off

The front panel label can be used as a guide to the hole positions for the switch and the potentiometer. The DC socket is located on the side of the case roughly above where IC1 is positioned.

Note that the DC socket could be a 2-pin DIN socket to suit the 4A current when Cuprothal is used as the resistance wire. Additionally, the plug connector for the supply would need to be changed to a DIN right-angle plug.

At the outlet end of the box, place the cable gland for the *Hot-Wire Cutter* connections.

When soldering the wires from the switch and potentiometer to the PC board, use heatshrink tubing over all connections except the switch terminals. Wires connecting to the switch terminals need to be soldered to the side of each terminal, with the lead exiting from the terminal side. This is because the switch sits almost on top of the PC board, when assembled in the box.

We secured the lid on to the case with only two screws placed at diagonal corners. The other two lid screw positions are used to secure the upside-down case (with lid) to the baseplate of the *Hot-Wire Cutter* using M3 × 30mm screws inserted from the underside of the wooden baseplate. The lid can be used as a template for the hole positions for drilling into the baseplate.

Note that when using M3 screws, the corner pillars of the box need to be tapped for an M3 thread. This can be done (preferably) using an M3 tap, or if you don't have one, using an M3 screw that has a filed notch along one side of the thread to provide a thread cutting edge. The remaining two corner pillars can be left untapped so that the supplied securing screws can be used.

Parts List – Hot-Wire Cutter controller

1 PC board, code 877, available from the *EPE PCB Service*, size 77mm × 50mm
1 UB5-size box 83mm × 54mm × 31mm, translucent blue or clear (or black/grey – see text)
1 front panel label 78mm × 50mm
1 2.5mm DC bulkhead socket
(or 1 2-pin DIN plug and 2-pin DIN socket – recommended for 4A use)
1 SPST mini rocker switch (S1)
1 knob to suit VR1
1 mini TO-220 finned heatsink 19mm × 19mm × 9.5mm
2 M205 PC board fuse clips
1 6A M205 fuse
1 cable gland for 3-6.5mm cable
1 10mm M3 screw and nut (for Q3 and the heatsink)
9 PC stakes
1 100mm length of light gauge red hookup wire
1 50mm length of light gauge green hookup wire
1 50mm length of light gauge white hookup wire
1 100mm length of 24 × 0.2mm figure-8 wire

Semiconductors
1 ICM7555IPA or LMC555CN CMOS timer (IC1)
1 IRF540 100V 32A N-channel MOSFET (Q3)
1 BC337 *NPN* transistor (Q1)
1 BC327 *PNP* transistor (Q2)
1 12V 1W Zener diode 1N4742 (ZD1)
1 16V 1W Zener diode 1N4745 (ZD2)
1 1N4004 1A diode (D1)
2 1N4148 switching diodes (D2, D3)
2 3mm LEDs (LED1 – red, LED2 – green)

Capacitors
1 100µF 16V PC electrolytic
2 100nF MKT polyester
2 10nF MKT polyester

Resistors (0.25W 1%)
2 2.2kΩ
1 100Ω
1 10Ω
1 10kΩ 16mm potentiometer (VR1)

Building the Hot-Wire Cutter

PERHAPS the best description of our *Hot-Wire Cutter* is of a miniature gallows, albeit without the hangman's noose.

As they say, a picture (or diagram) is worth a thousand words, so we'll save a few thousand by referring to the picture and diagram of our prototype cutter. They are pretty-much self explanatory.

For this particular size of cutter, a 9V 3A plugpack is suitable. You may care to change the dimensions if required, bearing in mind the comments about wire length and power requirements.

Ours uses a 240mm length of 0.315mm Nichrome 80 wire. With this length, the cutter can cut up to about a 230mm height of material; much thicker than you would normally expect to cut. Additionally, it can cut material in up to 240mm wide sections.

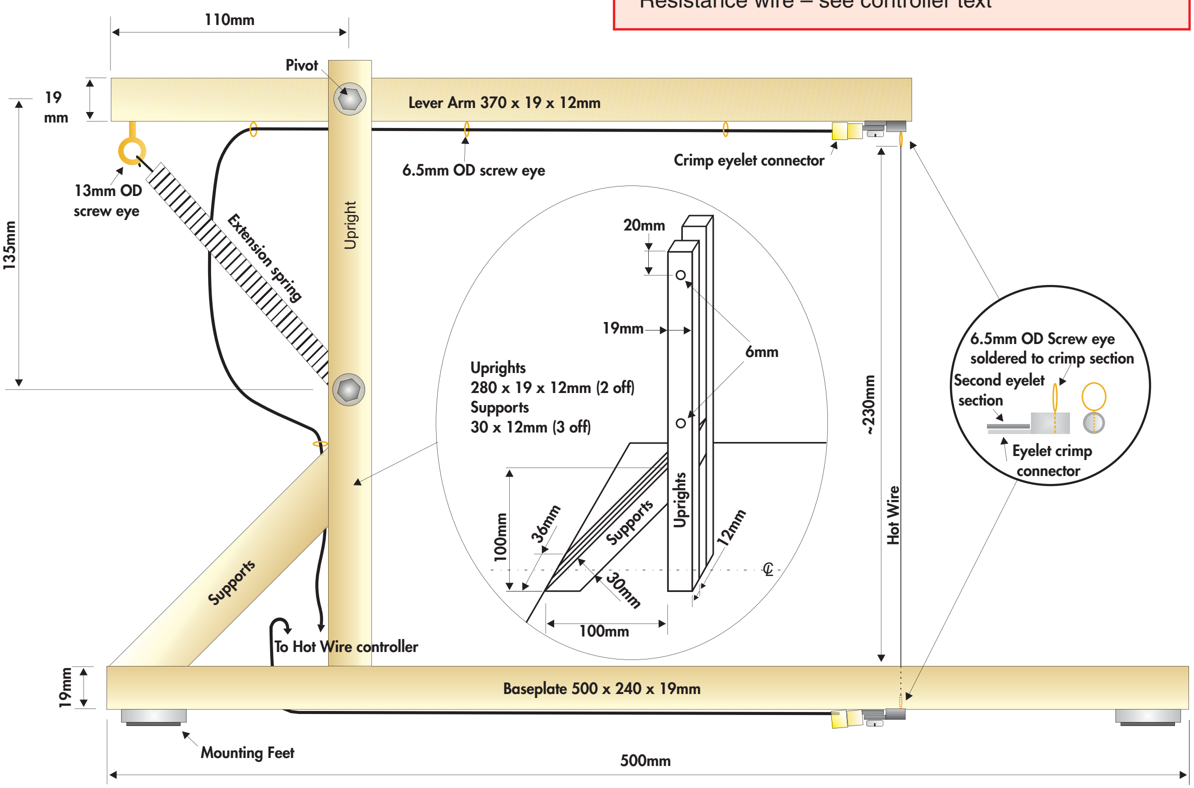
The cutter is made from dressed pine. A flat 19mm-thick baseplate (500mm × 240mm) supports two uprights (280mm × 19mm × 12mm) that in turn support a 370mm × 19mm × 12mm lever arm. This arm is pivoted at the top of the upright, while an extension spring provides the tension for the wire at the opposite end of the arm.

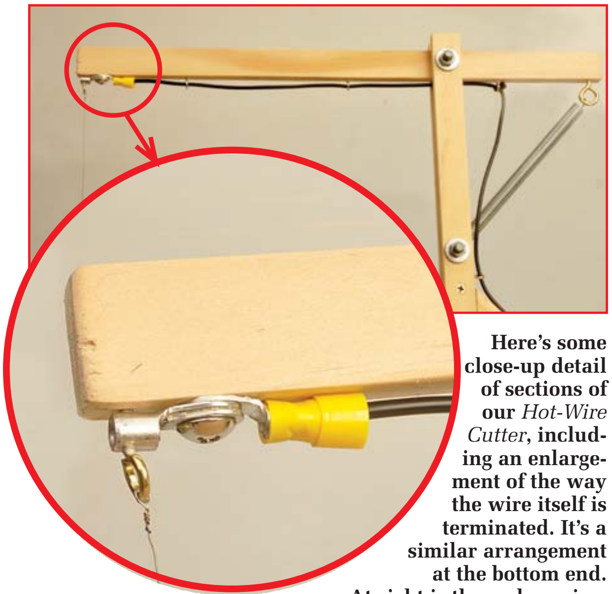
The baseplate sits on four mounting feet to allow room for the wiring and for the connectors to the lower hot wire attachment.

The lever arm pivots on a 6mm × 50mm bolt passing through the uprights, with 6mm washers between the lever arm and the uprights. The nut is not tightened up fully, so the arm has free movement (we didn't use one, but a locknut might be in order here).

Parts list – Hot-Wire Cutter
with a 240mm wire length

1 1m length of 19mm × 12mm DAR (dressed all round) pine
1 500mm length of 30mm × 12mm DAR pine
1 240mm × 19mm × 500mm pine or MDF board
1 extension spring, 9.525mm diameter × 95.26mm length × 1.041mm (eg, Century Spring Corporation C-215, available from Bunnings Hardware)
4 screw-on equipment-mounting feet 30mm diameter (eg, Jaycar HP-0830)
4 wood screws to suit equipment-mounting feet
1 brass-plated screw eye 3mm gauge 30mm long (13mm OD eyelet)
6 brass-plated screw eyes 1.6mm gauge 15mm length (6.5mm OD eyelet)
2 50mm M6 galvanised screws, with nuts
6 M6 washers
2 30mm M3 screws to secure the controller box to baseplate
6 crimp eyelets with 5.3mm ID hole and 6.6mm cable entry
2 8G × 12mm round head screws for timber
2 6G 25mm countersunk head screws for timber
1 1m length of 24 × 0.2mm Fig-8 wire
Resistance wire – see controller text





Here's some close-up detail of sections of our *Hot-Wire Cutter*, including an enlargement of the way the wire itself is terminated. It's a similar arrangement at the bottom end. At right is the end-on view of the spring assembly and pivot. While below right is the back of the baseboard, showing the Controller connecting wire and the four non-slip mounting feet.

One end of the tension spring attaches to the end of the lever arm with a screw hook, while the opposite end connects between the two uprights via another 6mm × 50mm bolt.

Connectors

Connectors for the hot wire itself are made using crimp eyelets and a 1.6mm gauge screw eye with a 6.5mm OD. The crimp section of the crimp eyelet has a small hole drilled through it and the screw eye is inserted into this hole and is soldered in place. To add strength to the assembly, the eyelet section of a second crimp eyelet is removed from its crimp section and soldered on top of the main crimp eyelet. The resulting connector is secured to the underside of the horizontal beam using an 8G × 12mm screw. Another crimp eyelet is also secured with this screw, and this is for connection to the wire that leads to the *Hot-Wire Cutter*.

The wire is supported using four small screw eyes spaced along the lever arm and down the upright, as shown in the diagram.

For the lower hot wire connection, the construction is the same, except that the assembly mounts beneath the baseplate that protrudes into a 10mm hole.

The hot wire wraps around the screw eyelet a couple of times and then around itself a few times to attach the wire at each terminal. The power wire leading to the *Hot-Wire Cutter* controller passes under the baseplate and then through a hole to access the controller.

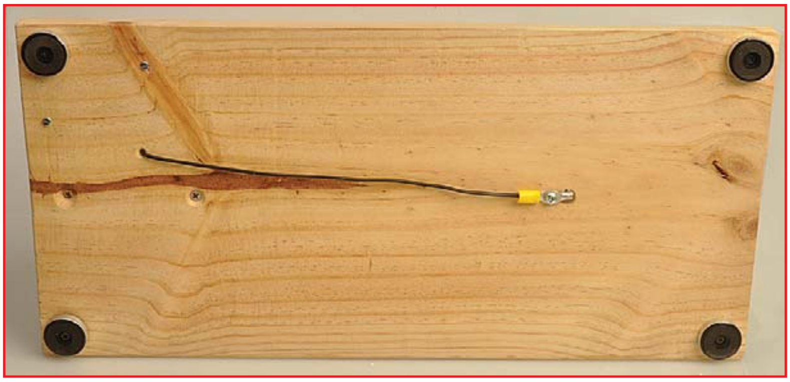
When positioning the hot wire terminal at the top horizontal beam, it should be such that the wire sits vertical when connected to the lower baseplate terminal.

Tension on the wire needs to be about 700g. This could be measured, but we found the easiest way was with the 'twang' test – when properly tensioned, plucking the cold wire should result in a note somewhere around middle 'C' – about 260Hz (if you don't have a piano or keyboard, Wikipedia has a note you can play [http://en.wikipedia.org/wiki/C_(musical_note)].

Spring tension sets the wire tension, and can be set by the positioning of the lower M6 bolt.

Spring tension will be greater than 700g. This is because the pivot point (or fulcrum) is not centred on the beam. For our design, the distance between the fulcrum and the hot wire is almost 250mm and the horizontal distance between the fulcrum and the spring attachment on the beam is 105mm. As a consequence, the spring is tensioned by about 700g × 250/105mm. This amounts to about 1.66kg.

Using the dimensions shown in the diagram, with a 230mm length of cutting wire (ie, fitted length) the specified 95.25mm-long spring is stretched to approximately 150mm.



Hot-Wire Cutter: resistance wire and power requirements

The type of wire and the wire length used in a Hot-Wire Cutter determine the power requirements for the supply that drives it. For 100W per metre, a 500mm length of wire requires up to 50W of power, while a 150mm length of wire only requires 15W of power.

How this translates into voltage and current is dependent on the actual wire used for the wire cutter. We know that the power is voltage multiplied by the current, but the value of current is dependent upon the wire resistance.

Several types of resistance wire could be used, but the two types of wire we recommend are Cuprothal 49 and Nichrome 80. Both are about 0.315mm in diameter, which provides a fine cutting edge.

Cuprothal 49 has a melting point of 1280°C and maximum continuous operation at 600°C. It is an alloy that comprises 44% nickel with 55% to 56% copper. Other metals in the alloy include about 1% magnesium and 0.5% iron. Cuprothal 49 is corrosion resistant and is used for precision resistors due to its very low change in resistance with temperature. The '49' designation refers to the resistive value of 0.49Ωmm^2/m value

Nichrome 80 has a melting point of 1400°C and maximum continuous operating temperature at 1200°C. Nichrome 80 is an alloy of 80% nickel and 20% chromium. It is also resistant to corrosion and is generally used for heating elements, such as toasters and hairdryers. The '80' value refers to the proportion of nickel in the alloy.

Melting points for Cuprothal 49 and Nichrome 80 are well above the melting points for polystyrene and polyurethane.

More information on these alloys can be found at www.kanthal.com/products/materials-in-wire-and-strip-form/wire/resistance-heating-wire-and-resistance-wire/. Note that the Nichrome 80 manufactured by this company is called 'Nikrothal 80'.

Resistance wire sources

Dick Smith Electronics (www.dse.com.au) sells both Cuprothal and Nichrome wire. They are 28B&S/AWG (about 0.32mm in diameter) and are 4m in length. The catalogue number is W3200 for the Cuprothal and W3205 for the Nichrome wire. Wire resistance for the W3200 is 6.08Ω/m and for the W3205, 13.4Ω/m.

Jaycar Electronics (www.jaycar.com.au) sells the Nichrome wire with catalogue number WW-4040. It is 28B&S at 0.315mm in diameter and 4m long with a resistance of 13.77Ω/m. Jaycar do not stock Cuprothal wire. (In the UK, the easiest way to buy sensible lengths of Nichrome wire is on eBay.)

Why the Dick Smith Electronics Nichrome wire has a slightly lower resistance per metre compared to the Jaycar Nichrome wire is possibly due to a slightly larger wire thickness or slightly different alloy composition. The different resistance values do not affect the current and voltage requirements to drive the wire to any noticeable degree.

For our calculations we used 6.08Ω/m for the Cuprothal wire and 11.4Ω/m for the Nichrome wire.

For Cuprothal, we calculate the required current and voltage noting that the power requirement is 100W/m and that power is the voltage squared, divided by the resistance.

The required voltage is, therefore, the square root of the power multiplied by the resistance. A similar formula for power is the current squared, multiplied by the resistance. In this case, the current is the square root of the power divided by the resistance.

These calculate to a current requirement of about 4.05A and 24.6V for a 1m length of wire. For shorter lengths of wire, the current requirement remains at 4.05A, while the voltage is reduced proportionately. For example, a 500mm length of wire requires 12.3V at 4.05A.

For the DSE Nichrome wire at 13.4Ω/m, calculations set the current at 2.73A and 36.6V/m. For the Jaycar Nichrome wire at 13.77Ω/m this equates to a current of 2.69A and 37.1V/m.

For different wire use these formulas to find the required voltage and current for a 1m length of the wire.

$$V=\sqrt{\text{(power requirement per metre x wire length in metres}^2\text{ x the wire resistance in }\Omega\text{/m)}}$$

$$I=\sqrt{\frac{\text{power requirement per metre}}{\text{the wire resistance in }\Omega\text{/m)}}}$$

Note that the power requirement per metre is 100W.

Also note again that the current (I) does not change with length because the resistance changes at the same rate as the power requirement. So, for example, a 500mm wire length requires half the power compared to 1m and so is 50W. The resistance is also halved compared to the 1m length.

Using different wire

We do not recommend using other wire for the wire cutter. Cuprothal and Nichrome wire are resistant to corrosion – this is something to take into account because when the wire is heated, corrosion is accelerated. Corrosion in this application is the formation of oxides of the wire alloy by reaction with oxygen in the air.

Having said that, some readers may wish to use resistance wire that they may have on hand or perhaps which is possibly easier to obtain. For example, one possible alternative is stainless steel wire, such as that used in boating and fishing equipment.

A typical stainless steel wire has a resistance of 0.9Ωmm^2/m, although this is dependent upon the grade. A 0.315mm diameter length of the wire has an area of 0.0779mm^2 and so 1m of wire will have a resistance of 11.54Ω. This resistance is calculated by dividing the wire area into the Ωmm^2/m value. Current requirements for this wire would be 2.9A at 34V.

Using a shorter length of this wire will set the required voltage to a lower value. A thicker gauge wire will increase the current requirement but lower the voltage requirement. It would be wise to measure the wire resistance to ensure it is suitable for a hot-wire cutter application before purchasing.

Other wire may not have a suitable resistance. When the wire resistance is too high, the voltage needs to be excessively high. Alternatively, when the wire resistance is too low, the current will be excessively high.

For example, steel piano wire typically has a resistance of 0.118Ωmm^2/m so 0.315mm wire will have a resistance of 1.51Ω/m. The wire would require just over 8A for a 1m length at a voltage of just over 12V. This is a high current, and is not suited for our Hot-Wire Cutter controller. Additionally, the steel wire is liable to corrode at the elevated temperatures of a wire cutter.

We get a similar result for a steel guitar string. We measured a light gauge E4 steel string for an acoustic guitar at 1.5Ω for a 660mm length. This is 2.27Ω/m. Its diameter was around 0.3mm.

Table 1 shows a list of standard switch-mode power supplies suitable for driving the shown Cuprothal and Nichrome wire lengths. These power supplies are either in plugpack form or are in-line power units. Alternative supplies include bench power supplies of a suitable current and voltage rating and batteries.

For example, a 12V lead/acid battery could be used as a 12V supply for the 487mm and 328mm wire lengths shown in the table.

The wire length does not need to be as precise as shown. A 519mm wire length, as expressed in the table, could be plus or minus 5%, or about 25mm longer or shorter without changing the cutting effectiveness of the wire cutter.

Wire length	Current @ full supply voltage	Standard switch-mode power supply rating	Wire type
Wire size: 28B&S (or AWG) or 0.315mm in diameter			
973mm*	4.05A@24V	24V 5A	Cuprothal
811mm*	4.05A@20V	20V 5A	Cuprothal
656mm*	2.73A@24V	24V 3A	Nichrome
770mm*	4.05A@19V	19V 5A	Cuprothal
519mm*	2.73A@19V	19V 3.2A	Nichrome
487mm	4.05A@12V	12V 5A	Cuprothal
410mm	2.73A@15V	15V 3A	Nichrome
365mm	4.05A@9V	9V 5A	Cuprothal
328mm	2.73A@12V	12V 3A	Nichrome
304mm	4.05A@7.5V	7.5V 5A	Cuprothal
246mm	2.73A@9V	9V 3A	Nichrome
205mm	2.73A@7.5V	7.5V 3A	Nichrome
164mm*	2.73A@6V	6V 3A	Nichrome
203mm*	4.05A@5V	5V 5A	Cuprothal
137mm*	2.73A@5V	5V 3A	Nichrome
*See note in text concerning use of the Hot-Wire Cutter Controller below 7V and above 17V.			

Table 1: standard switch mode supplies suitable for driving the indicated wire lengths and type for 100W/m. This power rating is suited for cutting polystyrene and polyurethane. A 24V lead/acid battery can be used for the 973mm and 656mm lengths. Similarly, a 12V lead/acid battery can be used with the 487mm and 328mm lengths.

Below is a list of the switchmode supplies listed in Table 1 from Jaycar (www.jaycar.com.au) and Altronics (www.altronics.com.au).

24V	5A	Altronics	M 8973
24V	4.2A	Altronics	M 8996
20V	5A	Altronics	M 8996
19V	5A	Altronics	M 8996
19V	3.2A	Jaycar	MP-3246
18V	5A	Altronics	M 8996
12V	5.4A	Altronics	M 8939
12V	5A	Jaycar	GH-1379
12V	5A	Jaycar	MP-3242
12V	3A	Altronics	M 8987A*
9V	3A	Altronics	M 8987A*
9V	3A	Jaycar	MP-3496
7.5V	3A	Altronics	M 8987A*
6V	3A	Altronics	M 8987A*
5V	3A	Jaycar	MP-3480
5V	3A	Altronics	M 8987A*
5V	3A	Altronics	M 8909A

*Multi-voltage/current outputs

Cutting other plastic types

While the 100W/m power into the wire is suitable for polystyrene and polyurethane, the cut tends to be slow with other plastics such as PET, ABS and acrylic (or perspex). For these, power requirement could be set higher for a faster cut. With power set at 180W/m, this has the wire glowing red hot. We recommend using Nichrome 80 wire due to its high continuous operating temperature. We do NOT recommend using Cuprothal at 180W/m.

At the 180W/m power setting, you can cut a PET bottle in half and cut long plastic IC carriers into separate sections suited for packaging individual ICs. When cutting ABS, acrylic or perspex, the edges will generally be a little rough and if clean edges are needed may require finishing with abrasive paper or a file. Cutting rate is about 1mm per second at full power.

We also tested the wire cutter for cutting nylon, such as used for PC board standoffs and for screws. This proved unsuccessful because the cut resealed itself as the wire passed through the material.

Other power supplies?

As we mentioned earlier, a 12V (or perhaps two 12V) lead/acid batteries could be used for the power supply in many instances. But if you have an old computer power supply, it might be possible to press that into service. Almost invariably, they have two individual outputs, 5V and 12V, (definitely not linkable for 17V!) and are usually rated at a minimum of 150W (~12A); some are much higher. Of course, the bulk of a computer supply is a consideration.

An alternative, much smaller, supply you might like to consider is one intended for a computer external hard disk drive or indeed a laptop. Generally, these are rated at between 12V and 19V or so, with currents from 2A to 5A and due to the huge numbers made, are often very low in cost.

Just beware, however, that some are not all that marvellous when it comes to quality control (or maybe even quality!): not long ago we purchased a couple of 12V external HDD supplies via the Internet and one of them, in the words of that old Hillaire Belloc poem, 'exploded with a loud report' the moment it was plugged into the mains. (OK, so together they only cost us $7.50 including postage from China . . . what did we expect?) *EPE*

Wire length	Current @ full supply voltage	Standard switch-mode power supply rating	Wire type
Wire size: 28B&S (or AWG) or 0.315mm in diameter			
489mm*	3.67A@24V	24V 5A	Nichrome
408mm*	3.67A@20V	20V 5A	Nichrome
387mm*	3.67A@19V	19V 5A	Nichrome
244mm	3.67A@12V	12V 5A	Nichrome
183mm	3.67A@9V	9V 5A	Nichrome
152mm	3.67A@7.5V	7.5V 5A	Nichrome
102mm*	3.67A@5V	5V 5A	Nichrome
*See note in text concerning use of the Hot Wire Cutter Controller below 7V and above 17V.			

Table 2: suitable switch-mode supplies to drive the hot wire at 180W/m for a given length. A 24V and 12V, lead/acid battery could be used for the 489mm and 244mm wire lengths respectively.

EPE EXCLUSIVE

Win a Microchip PIC32 USB Starter Kit 2

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip PIC32 USB Starter Kit 2. The PIC32 USB Starter Kit 2 enables users to develop USB-embedded host, device and OTG applications on the high performance PIC32 micrcontroller family.

The board contains an on-board programming/debugging, standard A USB and micro A/B connectors, and an expansion header compatible with the PIC32 Starter Kit and an expansion board such as I/O Expansion Board (DM320002) or for prototyping your own. The host PC requires a Windows-based operating system.
The USB Starter Kit 2 has the same form factor and expansion connector as other PIC32 Starter Kits.

This kit includes: • PIC32 USB Starter Board II • Standard-A-to-mini-B cable for debugger • Standard-A-to-micro-B cable for USB application development • Quick start card directing users to web-based instructions for software download and installation

HOW TO ENTER

For your chance to win one of three Microchip PIC32 USB Starter Kit 2, log on to:
www.microchip-comps.com/epe-usb2 and enter your details into the online entry form.

CLOSING DATE

The closing date for this offer is 31 December 2012

HEARING LOOP Level Meter

Last month, we described the circuit for the *Hearing Loop Tester* and gave the assembly details. This month, we show how to build a calibration coil and adjust the tester so that it gives accurate results. We also describe how the unit is used.

Part 2: By JOHN CLARKE

HAVING completed the assembly, the *Hearing Loop Level Meter* is ready to be calibrated. As previously mentioned, the unit must be adjusted so that the 0dB LED lights for a magnetic field strength of 100mA/m. This is done by placing the meter in a known magnetic field and adjusting the Calibrate trimpot VR1.

One possible method involves using a single one-metre diameter turn of wire fed with 100mA at 1kHz. An amplifier set to deliver 0.82V RMS via an 8.2Ω 0.25W resistor could be used to drive the coil.

However, to achieve correct calibration using this method, inductor L1 would have to be accurately located in the centre of the coil. That's because the field strength varies depending on L1's position relative to the centre position of the loop.

Helmholtz

A more practical calibration method involves using a Helmholtz coil (see **http://en.wikipedia.org/wiki/Helm holtz_coil**). A Helmholtz coil comprises two identical parallel on-axis coils that are driven by the same signal. These two coils are separated from each other by the coil radius (Fig.6).

A feature of a Helmholtz coil is that it gives a near-constant field along the axis between the two coils. This field remains constant to within 1% inside a central concentric area out to about half the diameter of the coil.

The current required in each coil to give a field strength of 100mA/m is 0.1398 × R/n, where 'R' is the radius in metres and 'n' is the number of turns in each coil. In our case, we decided to design the coils so that they have only one turn each (to make construction easy) and can be driven by the headphone output of a PC.

Coil construction

In practice, a 130mm-radius coil is suitable, and this requires a coil current of 18.16mA to give 100mA/m. This is achieved by connecting the coils in series and driving them with a 600mV AC signal via a 33Ω resistor.

Fig.6 shows the assembly details for our Helmholtz calibration coil. It's built using 2.4mm diameter steel (fencing) wire, a 200mm × 65mm length of timber, some hook-up wire and a 33Ω resistor. You will also need two screw terminals, a cable clamp, some shielded cable and a 3.5mm stereo jack plug.

As shown, the 2.4mm steel wire is looped to form two 260mm-diameter coils. To do this, first cut two 836mm lengths and bend them down by 90° about 10mm from each end. That done, drill two sets of 3mm-diameter holes at each end of the timber baseboard to hold the wire ends. Each hole pair should be 8mm apart and the two pairs should be separated by 130mm (see Fig.6).

The hook-up wire and 33Ω resistor can now be soldered to the ends of the steel wire. It's then just a matter of bending the steel wires into loops and feeding the hook-up wires and the

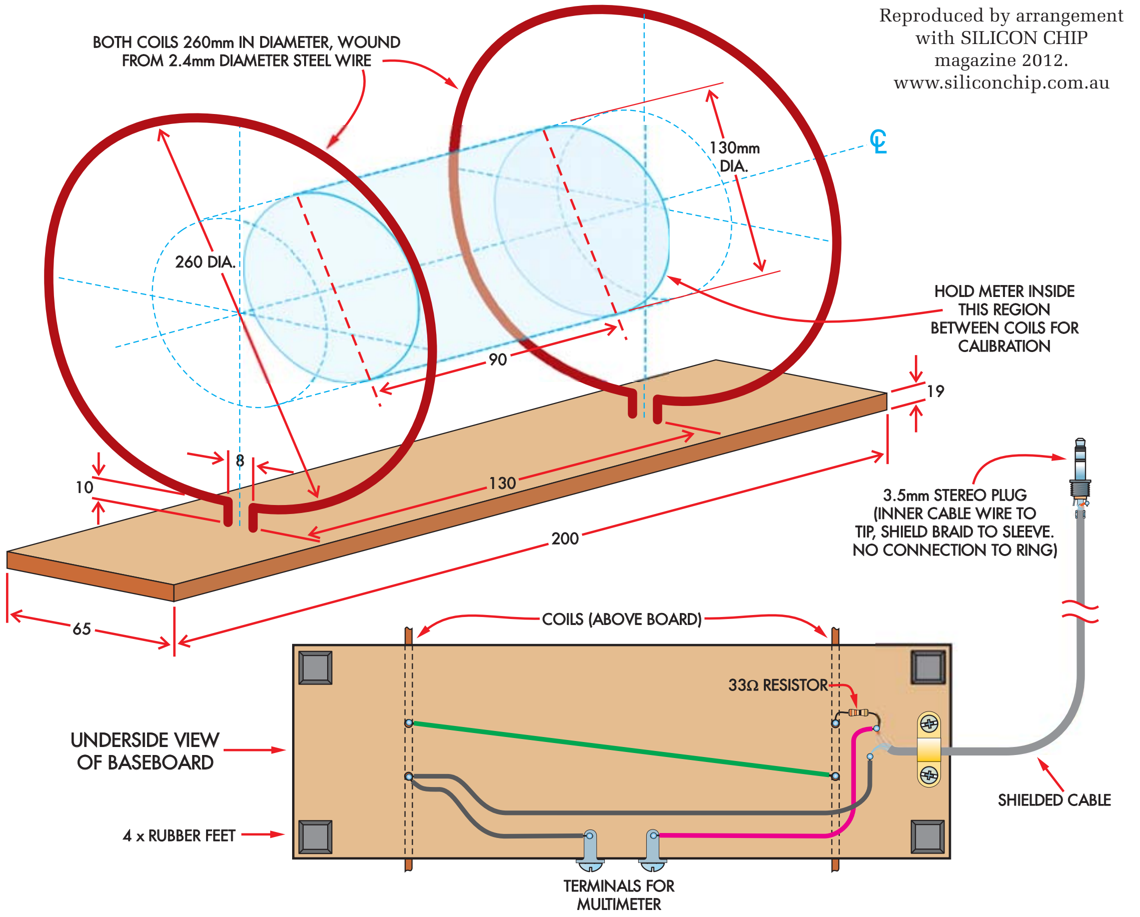


Fig.6: follow this diagram to build the Helmholtz calibration coil. The two loops are made from steel fencing wire and are connected in series and driven with a 600mV 1kHz sinewave signal via a 33Ω resistor – see text.

resistor down through the baseboard holes. The ends of the wire loops can be pushed into these holes to hold them in place.

Use small cable clamps (if necessary) to hold the coils in place and make sure that the ends of each coil don't short together. Use heatshrink to insulate them if necessary.

Once the coils are in place, follow the wiring diagram of Fig.6 to complete the connections to the multimeter terminals and the stereo jack plug. Note that the ring terminal of the 3.5mm stereo plug is left open circuit. **However, a mono jack plug cannot be used since it would short out the right channel of a stereo socket.**

The cable to the 3.5mm stereo jack plug is held in place on the baseboard using a suitable clamp. This clamp can be fashioned from some scrap aluminium or formed by soldering two solder lugs together.

Finally, adjust the two coils so that they are vertical and parallel to each other and are aligned along the same axis. However, while the construction needs to be reasonably accurate, it does not have to be perfect. Small variations in the coil radius and position do not affect the field strength by much, so this should be well within 3dB of the theoretical value.

Driving the coils

The coils can be driven using a 1kHz signal generator and a suitable amplifier to deliver a 600mV AC signal. Alternatively, you can use a software sinewave generator and the soundcard output from a PC to drive the coils. The latter method will be the most used, so we'll concentrate on that.

We tested two free software generators. The first comes from BIP Freeware and can be downloaded from: **www.electronics-lab.com/downloads/pc/005/index.html** It's available as a compressed file named *sine30.zip*.

To use this program, unzip the files to *c:\program files\sine30* and create a shortcut to *sine.exe* on the desktop. The controls are easy to use. **Make sure the mute is switched off and on again after every change in frequency, otherwise the signal becomes corrupted.** The output level can be varied over 255 steps using the volume control – see Fig.7.

The second recommended sinewave generator is available at: **www.diffusionsoftware.com/sinegen.php**

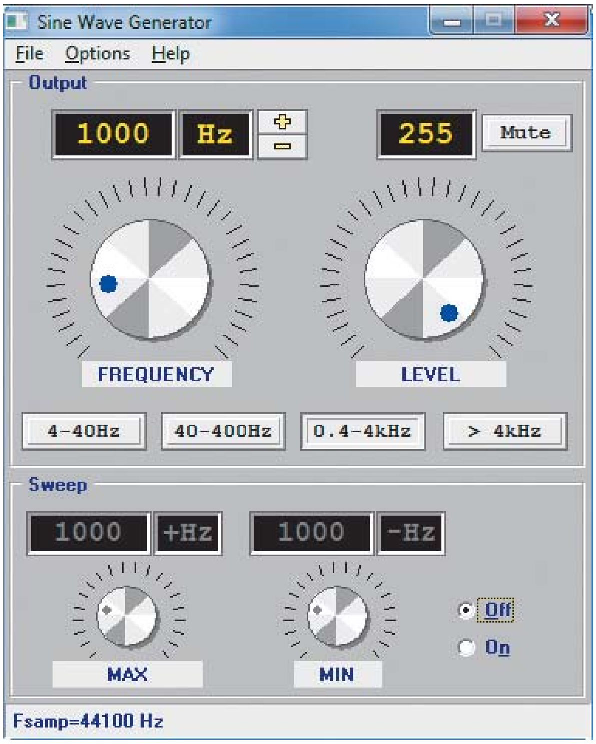


Fig.7: this software sinewave generator from BIP Freeware can be used to generate the 1kHz sinewave signal.

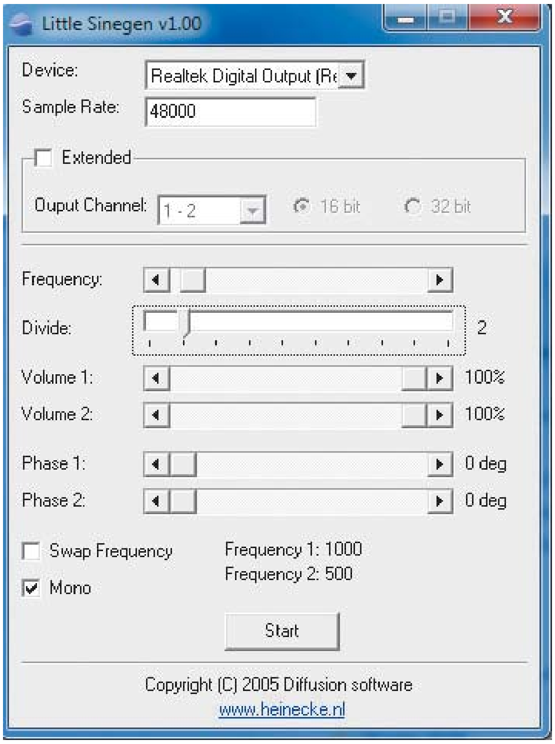


Fig.8: another suitable sinewave generator program is *Little Sinegen* from Diffusion Software.

Download and run the *SineGen _V1_0_setup.exe* file. The relevant files will be placed into *c:\Program Files\Little SineGen* and you should create a shortcut to *SineGen.exe* on the desktop.

Now run the program and select the soundcard driver. That done, set the output frequency to 1kHz by dragging the 'Frequency' and the 'Divide' sliders (the latter must be set to 1) – see Fig.8.

Depending on which program you choose, the output level is adjusted using either the level control or the volume control. If there are sound problems with either sine generator, go to the sound properties dialogs (eg, in Control Panel) on your PC and check the various audio level adjustments.

Setting the signal level

With the sinewave generator now operational and set to 1kHz, plug the Helmholtz coil assembly into the PC's audio output socket (green). The applied signal level should now be checked and adjusted using a multimeter that's accurate for readings up to 600mV at 1kHz.

If the meter is not accurate at this frequency, then set the generator to the highest frequency that the multimeter can accurately measure and adjust the level to 600mV. The output frequency should then be set back to 1kHz for the calibration.

As an example, the multimeter we used has a claimed accuracy of 2% from 45Hz to 500Hz on its lowest AC voltage range (3.2V). As a result, we set the sinewave generator to 500Hz, adjusted the output level for a reading of 0.6V AC on the multimeter and then set the generator back to 1kHz.

If your DMM is only accurate up to 50Hz, then it is not sufficiently accurate to set the level from a computer sound card. That's because most sound cards do not have a flat frequency response down to 50Hz, ie, the output level at 50Hz will be less than at 1kHz. Note, however, that you can adjust the level at 50Hz if you are using a 'standalone' signal generator and an amplifier, provided the amplifier has a flat response down to 20Hz.

Calibration procedure

During calibration, make sure that any equaliser settings on the computer (or tone controls on the amplifier) are set for a flat response. The calibration procedure is as follows:

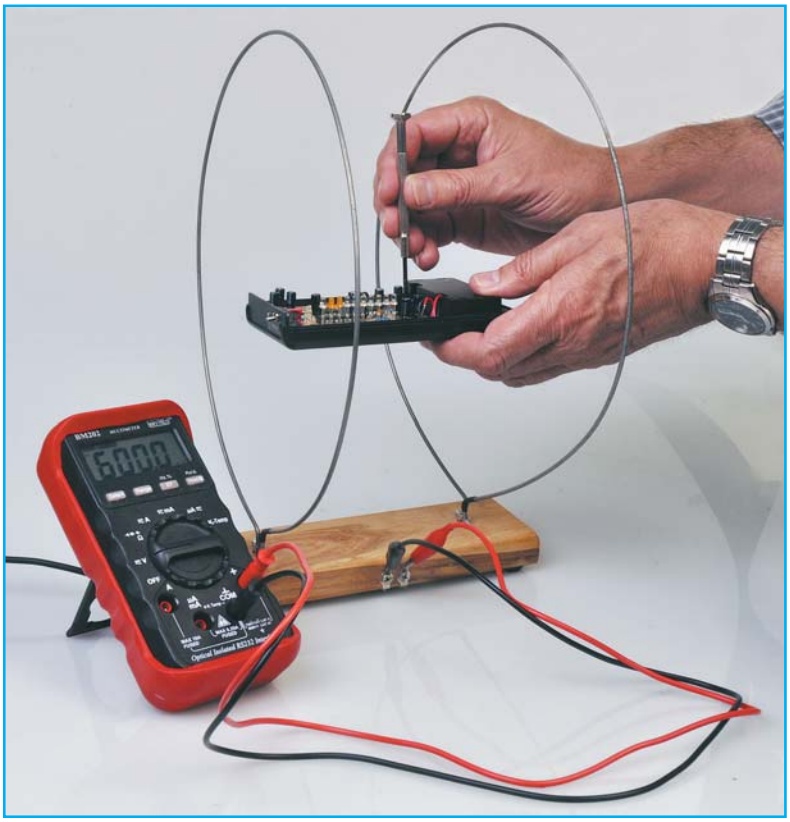
1) Set the driving signal level to 600mV AC and the frequency to 1kHz, as described above

2) Hold the *Hearing Loop Level Meter* (without its lid) between the two coils. The unit should be held horizontally (ie, with the LED bargraph horizontal) and with its pick-up coil (L1) centred within the measurement area

3) Adjust trimpot VR1 so that the 0dB LED (LED3) just lights.

4) Check that both coils are working by moving the *Hearing Loop Level Meter* along their axis. The signal strength should remain consistent at 0dB over the 90mm range depicted on Fig.6, and should be 3dB down (LED4 lit) if the pick-up coil is directly centred inside each coil.

If the signal strength varies along the axis (ie, within the 90mm range), it's probably because a coil is not working. In that case, check for shorts at the bottom of the coils, where they attach to the baseboard.



The *Hearing Loop Level Meter* is calibrated by holding it horizontally inside the centre-region of two wire loops and adjusting VR1 for a 0dB reading on the bargraph. The loops are driven with a 1kHz 600mV sinewave signal.

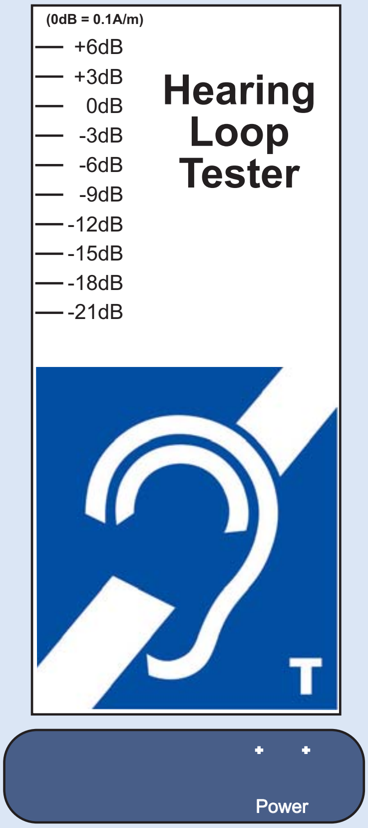


Fig.9: here are the full-size artworks for the front and top panels.

That completes the calibration procedure. The *Hearing Loop Level Meter* is now ready for use.

Checking background noise

Checking the background noise prior to installing a hearing loop is important. This will help ensure that the loop is not affected by excessive noise due to mains wiring and/or any nearby equipment.

According to Australian Standard AS60118.4-2007, environmental noise should not be any more than –20dB A-weighted with respect to a 100mA/m field (or –40dB with respect to a 1A/m field strength). At this level, the –21dB LED on the meter should either be off or just beginning to light.

Note that if a hearing aid loop is already installed, it must be switched off when making environmental noise measurements. **Note also that the unit must be held vertically when making both noise and field-strength measurements**.

In order to make the A-weighting measurement, jumper link LK1 must be out of circuit. However, before proceeding, we should comment on the AS60118.4-2007 environmental noise standard and the A-weighting used for the measurement.

Basically, the standard assumes that if the measured background noise level is 20dB below the 100mA/m reference level, then the area will be suitable for a hearing loop. However, our tests don't bear this out in practice.

Instead, we found that if the environmental noise is only just below –20dB with respect to the 100mA/m field, then the noise is too high for acceptable loop performance. In short, any signal from the hearing loop will be dominated by noise.

It seems that the measurement standard for background noise is not stringent enough. And the reason for this is that an A-weighted measurement response masks out the major source of noise which happens to be at 50Hz and 100Hz. A-weighting rolls off these frequencies at –30dB and –19dB respectively, before the noise measurement is taken.

Ditching A-weighting

We found that doing away with the A-weighting gives a better indication of background noise levels. **By installing link LK1, the meter has a much better response over the 50Hz to 100Hz region and this gives a better correlation between noise measurements and the noise that is actually heard in a hearing aid (or hearing loop receiver) when picking up loop signals.**

As a test, we set up a loop, fed it with an audio signal and monitored it with the *Hearing Loop Receiver* described in the September 2010 issue. We also monitored the signal levels using the *Hearing Loop Level Meter*.

We then introduced various noise sources to the loop (eg, a mains cord

connected to a fluorescent lamp) and checked the audible noise levels. By then turning the audio signal off, we were also able to check the noise levels on the tester.

This showed that the indicated noise levels on the tester were well matched to any audible noise from the receiver, but only when link LK1 was installed (ie, no A-weighting). With A-weighting selected, the meter gave no indication of background noise, even when it made listening to the wanted signal quite difficult.

So we recommend leaving link LK1 in position when making noise measurements. In this configuration, noise levels will be satisfactory if they are at –21dB or less, assuming the meter is correctly calibrated (ie, either the bottom-most LED or no LEDs should light). This measurement recommendation is actually more stringent than the AS60118.4-2007 environmental noise standard.

Field-strength measurements

Field strength measurements should be made using a 1kHz sinewave as the signal source for the loop amplifier. If you do not have a signal generator, you can use one of the software generators described earlier – see Fig.7 and Fig.8.

If the hearing loop is a part of a sound system which also uses loudspeakers, the 1kHz tone should be set to the normal listening level. The hearing loop amplifier is fed with a signal from the main sound system.

It's then just a matter of adjusting the signal level from the hearing loop amplifier so that the 0dB LED just lights on the meter.

By increasing the driving frequency (but keeping the level the same), you can use the meter to check the frequency response of the loop from 1kHz to 5kHz. This will show up any high-frequency drop-off in the field strength due to inductance effects in the loop.

Generally, it's not necessary to check the loop response below 1kHz since inductance effects do not affect low frequencies. It's not necessary for the low-frequency response of the hearing loop to go below 100Hz.

If you do decide to check the loop's response down to 100Hz, remember that the tester rolls off its low-frequency response. For the wide setting, with link LK1 inserted, its response is 3dB down at 200Hz and 6dB down at 100Hz. This means that if the meter reads –6dB at 100Hz, then the loop response is actually flat to 100Hz. Similarly, if the meter reads –9dB at 100Hz, then the loop response is –3dB at 100Hz.

Final checks

Once the signal levels have been set and the frequency response checked, the loop can be tested with normal programme material, such as speech. If the amplifier includes a VU meter, adjust the volume control to give the same average VU level as for the 1kHz sinewave signal. Peak levels on the VU meter should be ignored.

The *Hearing Loop Level Meter* can also be used to set the amplifier output to provide the correct 0dB level with normal programme material. In practice, measured loop field strength levels will vary depending on the signal applied to the loop. If the loop amplifier includes a compressor or if the *Hearing Aid Loop Signal Preconditioner* (to be described) is used, then the signal level will be relatively constant.

Finally, note that the meter has a slow response. This has been done so that it averages the signal level over time. This allows it to display the long-term average level without indicating individual signal peaks (which would be misleading). *EPE*

Jump Start

By Mike and Richard Tooley

Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our new series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series will have a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages 75-77 in this issue).

Each of our Jump Start *circuits include the following features:*

- ***Under the hood* –** provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes* –** has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard* –** used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real* –** introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further* –** provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery* –** shows how we developed and built each of the projects.

Coming attractions

Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012 ✓	Solar mobile phone charger	Away from home/school
September 2012 ✓	Theft alarm	Protect your property!
October 2012 ✓	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012 ✓	Frost alarm	Beginning of winter
December 2012 ✓	Mini Christmas lights	Christmas
January 2013	iPod speaker	Portable Hi-Fi
February 2013	Logic probe	Going digital!
March 2013	DC motor controller	Ideal for all model makers
April 2013	Egg Timer	Boil the perfect egg!
May 2013	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

Merry Christmas

Mindful that Christmas will soon be upon us, this month's Jump Start *features a simple lighting sequencer that you can use to produce a variety of seasonal light displays. Our* Mini Christmas Lights *sequencer can control up to 16 lights arranged in four groups, making it possible for you to produce some novel and attractive lighting displays – just right for the festive season!*

Under the hood

The *Mini Christmas Lights* sequencer circuit uses only two integrated circuits (ICs) and a handful of other low-cost components. It is designed to work with a variety of lights, including standard and high-intensity light emitting diodes (LEDs) and small filament lamps. The circuit provides four output channels, each capable of driving up to four outputs (making a total of 16 individual light sources).

The simplified block schematic of our *Mini Christmas Lights* sequencer is shown in Fig.1. The timing signal, a variable frequency square wave, is

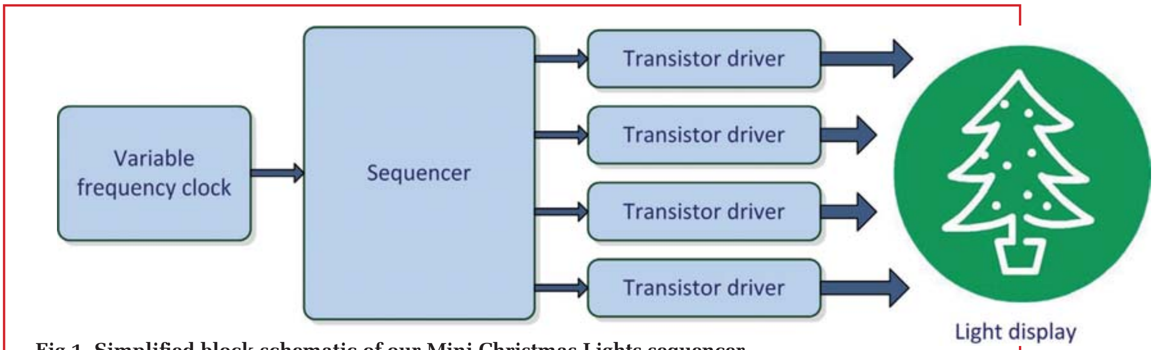


Fig.1. Simplified block schematic of our Mini Christmas Lights sequencer

derived from a clock oscillator (more on this later).

The output of the clock drives a counter that provides a sequenced output which can be configured so that it repeats its counting sequence based on any number between 1 and 10. In other words, the counter can count any number up to 10 with outputs that will appear in a sequence.

Schmitt trigger

Many of our earlier *Jump Start* projects have made use of a conventional 555 astable oscillator for generating a square wave signal. This month, we shall introduce a new (and even simpler) method of generating a square wave using a special type of logic circuit. This family of logic devices has switching characteristics that delay the switching action until a specific threshold is reached in the input level.

The circuit is sometimes referred to as a 'Schmitt trigger' because the output retains its value until the input has changed sufficiently to trigger a change at the output. It's worth explaining this in a little more detail in relation to a simple (non-inverting) buffer stage, as shown in Fig.2. (Note that Fig.2(a) shows the symbol of a conventional non-inverting buffer, while Fig.2(b) shows a Schmitt version of the same gate.)

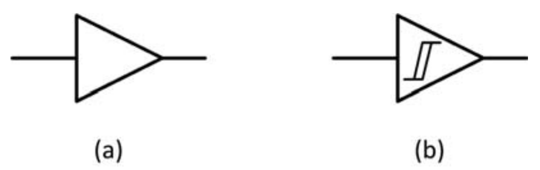


Fig.2. (a) A conventional logic buffer, and (b) a buffer device based on Schmitt technology

In the case of Fig. 2(a), the output of the conventional logic device will change from logic 0 (low) to logic 1 (high) whenever the input rises *above* the nominal input threshold voltage. Similarly, the output of the conventional logic device will change from logic 1 (high) to logic 0 (low) whenever the input falls *below* the nominal input threshold voltage.

On the threshold

The Schmitt logic device shown in Fig.2(b) has two thresholds; a positive going threshold, and a negative going threshold. The upper threshold typically occurs at about 60% of the supply voltage, while the lower threshold normally occurs at around 40% of the supply voltage.

The difference between the two switching thresholds (which causes an effect referred to as 'hysteresis') is equivalent to about 20% of the supply voltage. In the case of a conventional CMOS Schmitt logic device operating from a 5V supply, the hysteresis range will be about 1.5V to 2V.

The hysteresis effect delays the switching action so that a rising edge change in input voltage will have no effect on the output state until the input passes the upper threshold voltage. Thereafter, when the input level starts to fall again, the output will not revert to its earlier state until

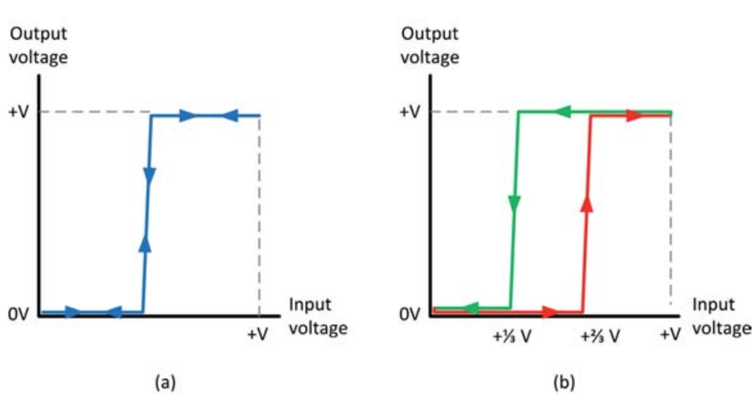


Fig.3. Response of (a) a conventional logic buffer, and (b) a Schmitt buffer when fed with a change of input voltage

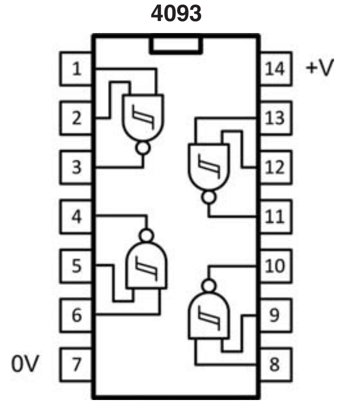


Fig.4. The 4093 quad two-input Schmitt NAND gate pinout configuration

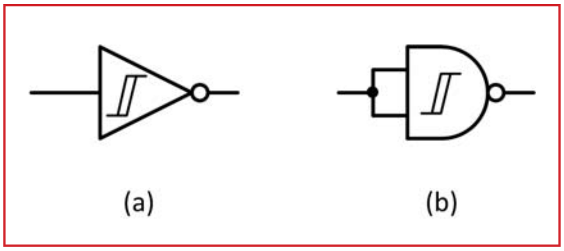


Fig.5. The Schmitt inverting buffer shown in (a) can be produced by connecting the two inputs of a NAND gate together, as shown in (b)

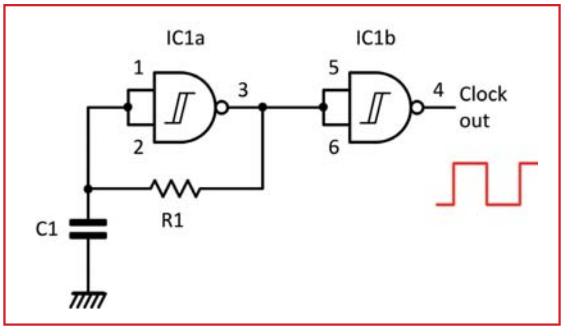


Fig.6. A very basic Schmitt logic oscillator circuit

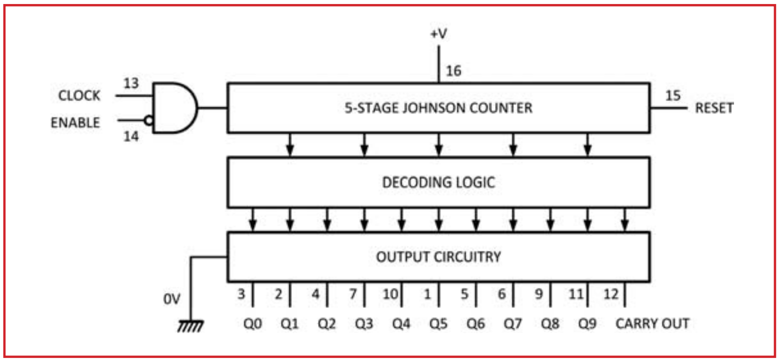


Fig.7. Simplified internal block schematic for the 4017 CMOS decade counter IC

the *lower* threshold is reached. Fig. 3 illustrates this action in relation to a rectangular input pulse. Notice the shape of the graph – you will see that this is reflected in the symbol for the buffer shown in Fig.2(b).

Design notes

We can put the delayed action of a Schmitt logic device to good use in the form of a very simple logic oscillator based on a 4093 quad two-input Schmitt NAND gate, as shown in Fig.4. We have chosen the 4093 device because it is inexpensive and commonly available, but we could equally have used a hex inverting buffer, such as the 40106.

However, by simply connecting the two inputs of a two-input NAND gate together, as shown in Fig.5(b), we can produce an inverting buffer, as shown in Fig.5(a).

A very simple Schmitt logic oscillator circuit is shown in Fig.6. When the supply is first connected, capacitor C1, will be uncharged and, as a result, the input voltage to IC1a (pin 1 and pin 2) will be held low.

Since IC1a is configured as an inverter its output voltage (pin 3) will be high (ie, the opposite logical state). C1 will then begin to charge with current supplied by resistor R1. The charging process will continue until the voltage dropped across the capacitor reaches the upper threshold voltage (about 60% of the supply voltage). At this point, the output will suddenly fall to the low state (approximately 0V) and the capacitor will then start to discharge through R1. IC1b is added to form an inverting buffer stage, which helps to clean-up the waveform and improve the performance of the clock oscillator.

After a short time interval, the voltage dropped across the capacitor will have fallen to the lower threshold voltage (about 40% of the supply) and the output voltage will suddenly rise to the high state (approximately equal to the supply). The cycle of charge and discharge will then continue indefinitely (or at least until the supply is disconnected), with an output waveform from pin 3 of IC1 consisting of a square wave with equal high and low times. The frequency of the square wave output will depend on the values used for C1 and R1; increasing the time constant (ie, the product of C1 and R1) will cause the output frequency to fall, and *vice versa*.

Illumination

Having generated a logic-compatible square wave clock signal to control the timing of our light display, we next need to produce signals that will result in the sequential illumination of the LEDs (or miniature filament lamps) that make up the light display. For

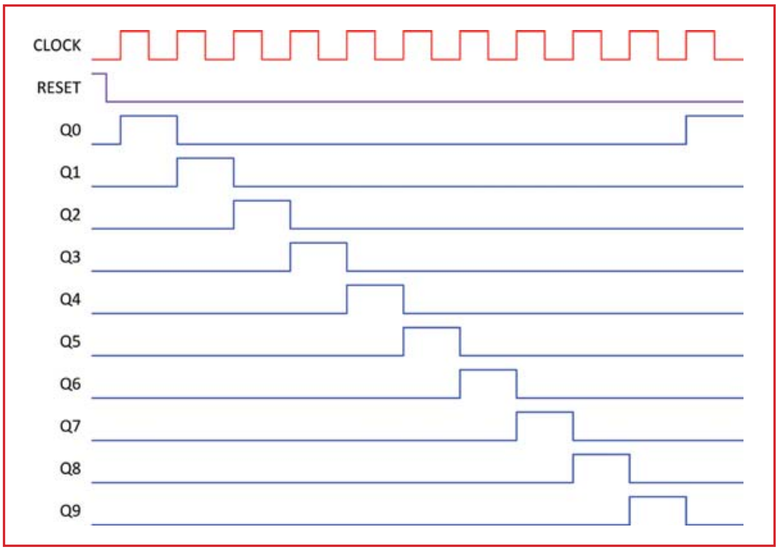


Fig.8. Output timing diagram using the 4017 decade counter

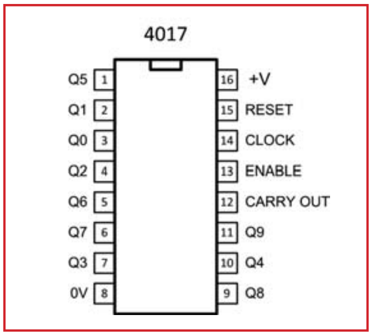


Fig.9. The 4017 decade counter pin connections

this, we are using a dedicated counter chip, the 4017, which comprises a Johnson counter together with the necessary decoding logic and output circuitry to activate each of its ten outputs in sequence when fed with a square wave clock signal.

The simplified block schematic of the 4017 device is shown in Fig.7. Note the additional ENABLE and RESET inputs. The former needs to be taken high to feed the clock signal to the five-stage Johnson counter, while the latter needs to be held low in order to continue counting, as shown in Fig.8. The pin connections for the 4017 are shown in Fig.9.

Get real

The Schmitt NAND gate oscillator (see Fig.10) can be very easily tested using Circuit Wizard. Having constructed the virtual circuit, you will need to add an oscilloscope to display the waveforms.

To do this, you should select Gallery then Test Equipment, Virtual Instruments and finally drag and drop the oscillscope symbol into the Circuit Diagram before making the connections, as shown in Fig.11. The waveforms will be drawn superimposed on the graph scale (XSC1 in this case).

To make the best use of the graph you will need to adjust the maximum and minimum voltages and time scale, as shown in Fig. 12. Finally, you might notice that the first cycle of the square wave output is slightly different from all of the subsequent cycles, as shown in Fig.13. This is because the capacitor, C1, is initially uncharged and the time taken to reach the upper threshold switching voltage will consequently be noticeably greater than for subsequent cycles. In the long term, of course, this isn't a problem.

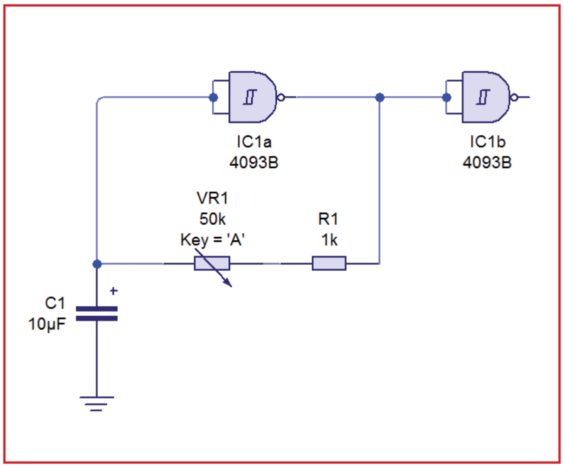


Fig.10. The Schmitt NAND oscillator in Circuit Wizard

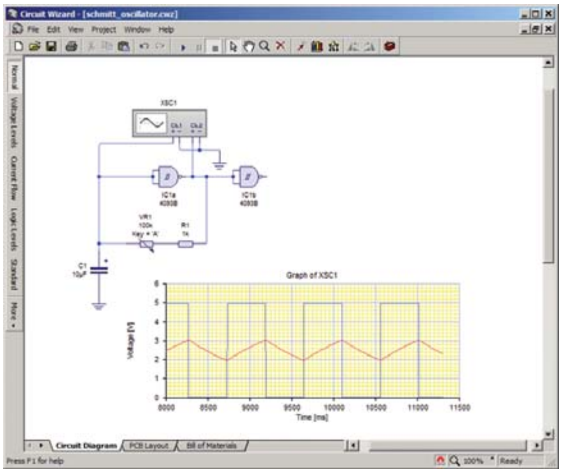


Fig.11. Adding a virtual oscilloscope to display the circuit waveforms

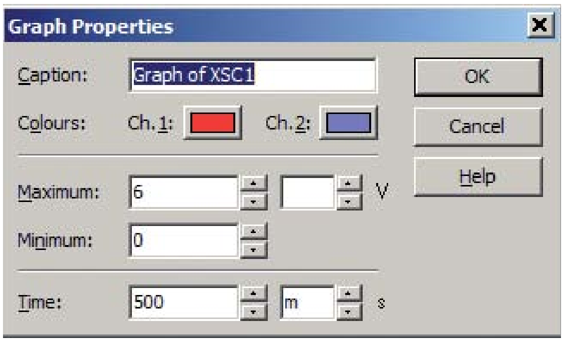


Fig.12. The Graph Properties dialogue box (the values shown will produce an easily readable waveform)

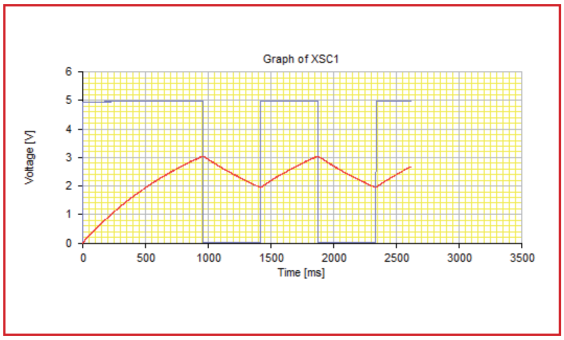
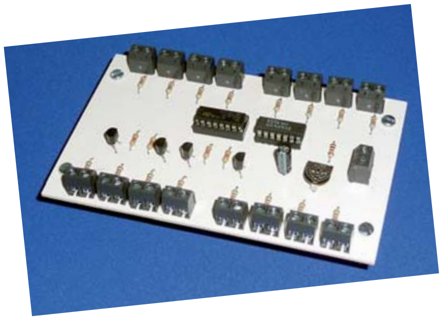


Fig.13. The first cycle of operation showing the initial charging curve and subsequent oscillations



Mini Christmas Lights – using Circuit Wizard

NOW THAT WE'VE investigated the underpinning theory, let's look at this month's practical build project. Fig.14 shows our complete *Mini Christmas Lights* sequencer circuit diagram, shown with four LEDs and a transistorised output from the 4017 (IC2).

Go ahead and enter the circuit in Circuit Wizard and try out its operation by simulating it. If all has gone well, the four LEDs should be illuminated in turn. Varying trimpot VR1 will alter the period of illumination for each count.

Final circuit

Now that we're happy with how the circuit simulates, we need to modify it a little to fit the requirements of our real output circuit before moving on to the PCB design stage. Fig.15 shows our modified version. We've removed the four individual LEDs and instead inserted a series of two-pin screw terminal connectors to create four 'channels'.

For each of the four channels we've inserted four screw terminals to support a total of 16 LEDs. Each screw terminal has both a supply connection and a switched ground connection through a series resistor. The value of the series resistors may be modified to suit the voltage/current requirements of your chosen output. In this case, we've used a 220Ω resistor to suit a standard 5mm LED.

The number of connections on each channel may easily be reduced or increased, but you need to be mindful of the current limitation of the switching transistors. If you require more powerful outputs you may need to consider using higher power transistors. As we noted earlier, further channels could also be added

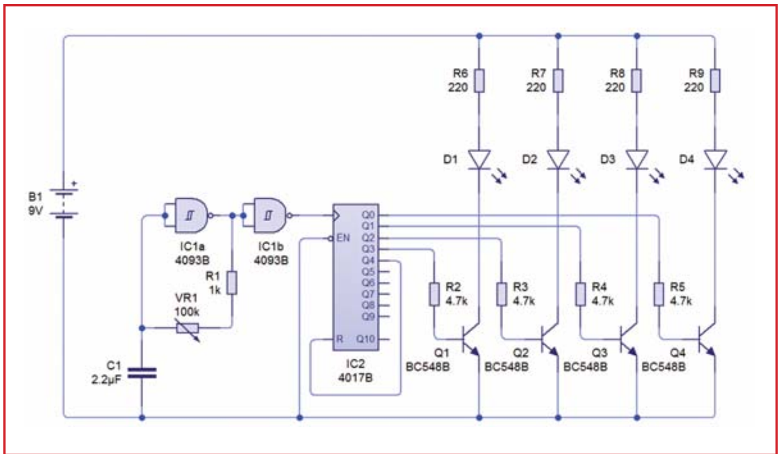


Fig.14. The complete circuit of our Mini Christmas Lights sequencer

You will need...

Mini Christmas Lights

1 PCB, code 879, available from the *EPE PCB Service*, size 126mm × 79mm

17 Two-way PCB mounting terminal blocks

1 battery clip, plus leads for a PP3-type battery (for test purposes)

1 9V (PP3-type) battery (for test purposes)

1 9V DC mains power supply rated at 200mA min. (for normal operation)

4 PCB mounting pillars

Semiconductors

1 4093B CMOS quad inverting Schmitt NAND (IC1)

1 4017B CMOS decade counter (IC2)

4 BC548B *NPN* silicon transistors (Q1 to Q4)

16 Coloured LEDs (not shown in Fig.15)

Resistors

1 1kΩ (R1)

4 4.7kΩ (R2 to R5)

16 220Ω (R6 to R21)

(VR1) 100kΩ miniature skeleton preset

Capacitor

1 2.2µF (C1)

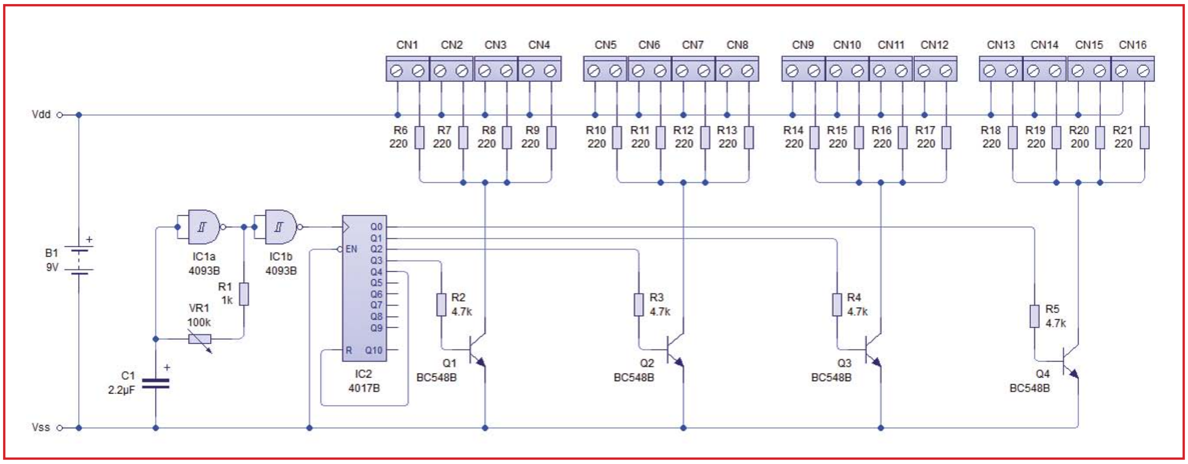


Fig.15. Modified version of Mini Christmas Lights sequencer

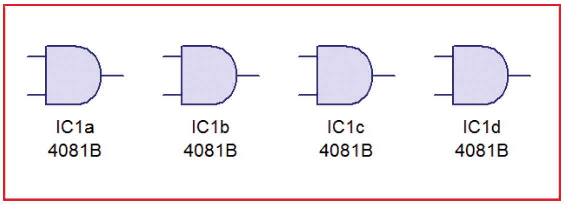


Fig.16. Circuit Wizard automatically assigns logic gates to a particular chip package (in this case a 4081 quad NAND gate)

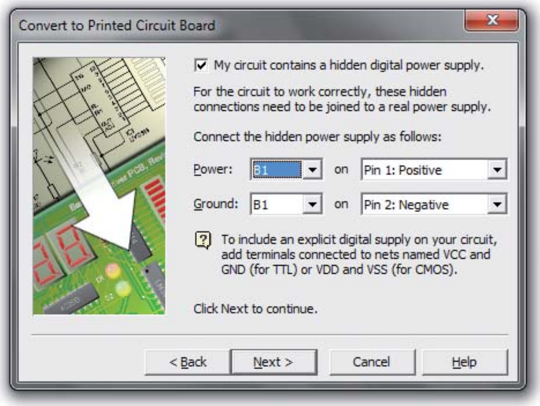


Fig.17. Circuit Wizard's 'Convert to PCB' dialogue box

by repeating the transistor arrangement and moving the reset signal line to a later output bit.

Logic gates

When designing logic-based circuits in Circuit Wizard you are able to add individual logic gates to your schematics. In a circuit you may only require one or two gates of the same type. However, logic chips generally contain several of the same type of gate in one physical package. When adding gates, Circuit Wizard will automatically assign the gates you draw to a chip package appending a letter to each gate within each device until all of its included gates have been allocated (Fig.16). Note that you are able to manually override the specific selection of the gate, for example if it would make the physical connections easier in a PCB.

Another point to note is that when adding logic gates you do not have to explicitly add power connections to the devices. Circuit Wizard has a 'hidden power supply' feature; it will automatically make these connections for you in the background. Similarly, when converting to a PCB, it will add these required connections. This may be altered when following within the customised PCB conversion wizard process (Fig.17).

Note that in some circumstances you may wish to explicitly add these connections to your circuit, for example to give a more representative simulation or to be specific about power supply connections. In this case, you would need to add Vss and Vdd power terminals (Vcc and Gnd if using TTL variants) to your circuit. You'll find these in the component gallery under Power Terminals, as shown in Fig.18 (don't simply add a plain terminal and name it!). This may also resolve quality check errors associated with the power connections (we found this to be the case when producing our prototype PCB). It is possible to turn off or edit the hidden power supply option in: Project > Simulation > Power Supply... under the Simulation tab, as shown in Fig.19(a) and Fig.19(b).

A note regarding Circuit Wizard versions:

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.

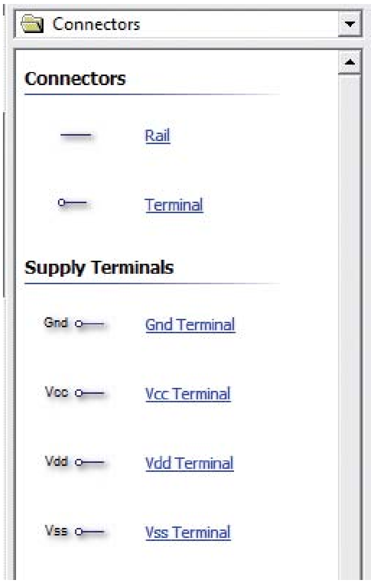
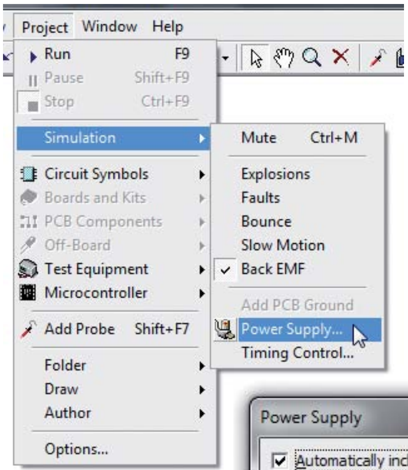
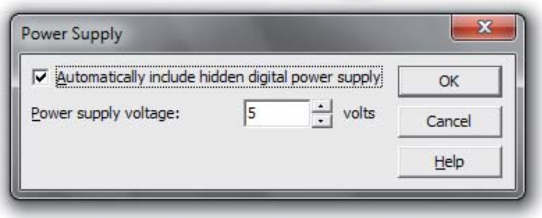


Fig.18. Connectors and power supply terminals can be added from Circuit Wizard's Gallery of component parts



(a)



(b)

Fig.19. Using Circuit Wizard's menu and dialogue box options to (a) first select the Power Supply and (b) select the required pin connections

Circuit board

Our final PCB design was then produced from our 'virtual' schematic shown in Fig.20. However, before we actually create the physical PCB we can test the unit by wiring up a battery and off-board LEDs, as shown.

This is a really nice way to check that your PCB operates as you would expect before moving on to production (in addition to, the as-ever important quality check). In fact, we mimicked almost exactly the same arrangement to test the unit once produced (see Photo Gallery).

If you don't want to produce your own board, a pre-made PCB can be purchased from the *EPE PCB Service*, code 879 (see page 78).

As we discussed earlier, the board will sequence the four channels in turn according to the clock frequency generated by the Schmitt oscillator arrangement, and varied by the variable preset (VR1). You can create a number of different effects depending on how you physically present the LEDs. ***Here are just a few ideas for you to experiment with:***

- A 'running light' effect, where a string of lights appears to move or run along its length may be made by situating one of each of the LEDs from each channel in sequence; ie, A, B, C, D, A, B, C, D etc.
- A random effect may be obtained by positioning the LEDs in a random channel order. Although several of the LEDs will illuminate on each step, this can be quite effective.
- An animation effect can be created by using LEDs on each channel to outline or illuminate staged movements; eg, a swinging bell, waving hand, nodding head.

It is possible to wire outputs individually to each screw terminal (ie, with two wires), or you may wish to run a common supply line and only wire back the negative side of the LEDs to the switched side of each connection. We've designed the sequencer to be easy to produce and versatile in operation.

A simple option is to cut festive shapes (either manually or using a laser cutter/CNC mill) with 5mm holes to allow LEDs to be poked through up to their neck. A small drop of superglue or hot melt glue from a glue gun can be used to secure them in place with wiring hidden on the reverse.

How you put the light sequencer in to action is totally up to you; from a string of lights to decorated ornaments and animated shapes, the only limit is your ingenuity and imagination!

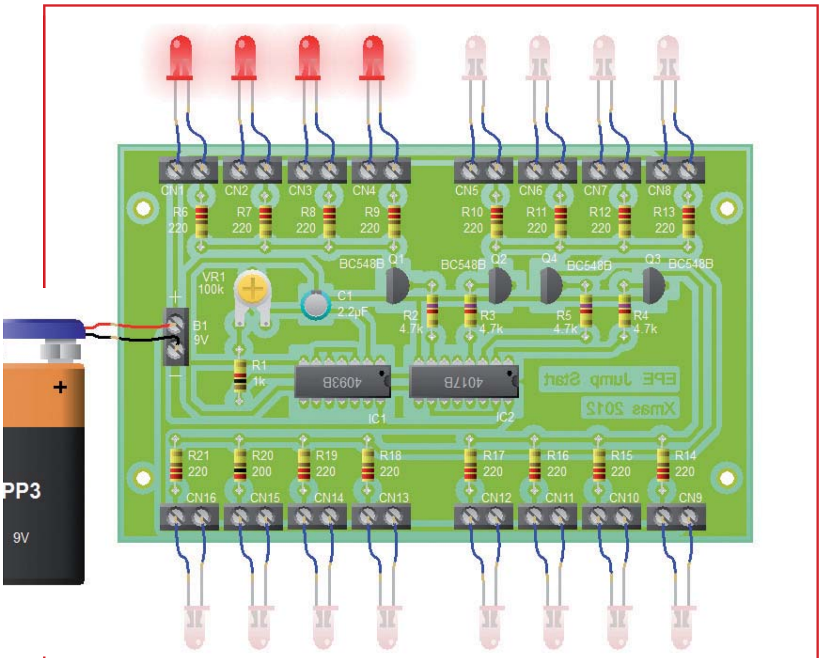


Fig.20 (above). Testing the complete virtual circuit prior to PCB production

(below) Practical PCB track layout viewed 'through' the board. Final PCB size is 126mm by 79mm

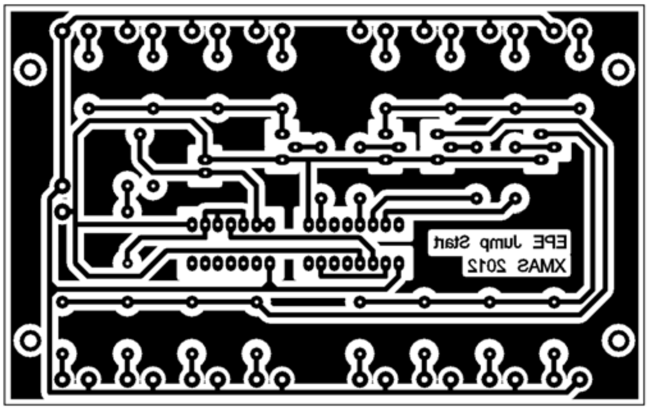
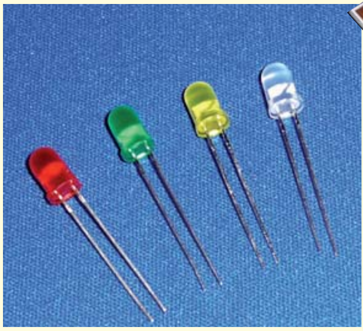
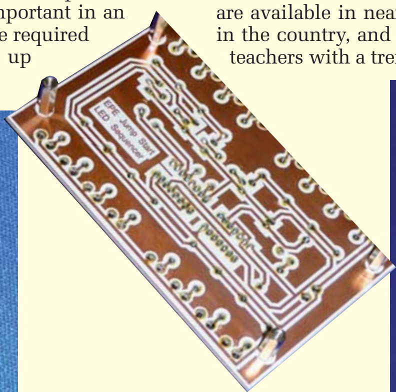


Photo gallery...

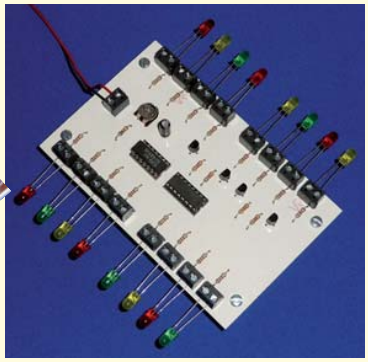
The gallery is intended to show readers some of the techniques that they can put to use in the practical realisation of a design. This is very important in an educational context, where learners are required to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding. The techniques that we have used are available in nearly every secondary school and college in the country, and we believe that our series will provide teachers with a tremendously useful resource.



Coloured LEDs can be used to make some great displays!



Track side view of an early prototype PCB showing neat soldering!

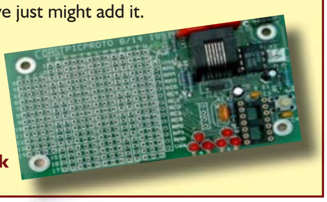


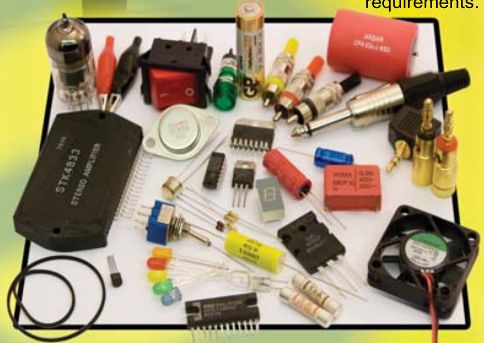
The finished PCB with LEDs connected for final testing prior to installation

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

Next month

In next month's *Jump Start*, we shall be jumping into the world of analogue electronics and building a simple amplifier that can be used with portable audio equipment, such as CD and MP3 players, tablets and laptop computers – perfect for all those Christmas gifts that don't produce quite enough sound!





PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Relocatable assembly

AFTER a summer recess (caused by a complicated and protracted house move by the author) we return to the subject of developing an understanding of the fundamentals of writing software for PICs, focusing on the low cost, yet powerful and easy-to-use PIC18F27J13. In our last article we looked at the 'absolute assembly' method for writing assembly language programs; this month, we look at the more complicated but more powerful technique of 'Relocatable assembly'.

In absolute assembly, the user is responsible for telling the assembler program not only the assembly language instructions to use, but also their precise location within memory; where code will be located in FLASH, and where each variable will be held in RAM. This technique is limiting and rather error prone – the assembler will not check to see whether you have accidentally placed two variables at the same location, nor will it check that you have spaced the gaps between variables sufficiently to allow for the space you require.

This is a frequent cause of difficult-to-track-down bugs; you position a 20 byte buffer at location 0×40, and then accidentally place an index variable at location 0×50. These kind of errors result in hours of debugging, which is fine if you enjoy that activity, but most of us don't!

Having to tell the assembler exactly where your code should be placed also limits the ease with which code can be re-used; wouldn't it be great if you could design a program subroutine to perform some specific purpose, build it, test it, and then be able to simply add it to any future project without having to edit the code again? This is where relocatable assembly comes in, and introduces the use of a new utility program called the 'linker'.

Linker

The linker is a program (supplied as part of the Microchip MPLAB suite) that is responsible for gluing together bits of pre-assembled source code. Each source file is assembled once by the *relocatable assembler* and turned into an object file containing the PIC instruction codes in binary format.

When building a project consisting of a number of source files, the linker will search all of the object modules and 'fix up' all the addresses of subroutines called, wherever they are. It sounds like a complex process, but it's straight forward: glue all the bits of code together, find the addresses of all symbols, then go and write those addresses into the object modules that reference them.

The linker program understands where everything can go (such as the size of the code and data spaces available) through the use of a 'linker script' specific to each processor. You can specify this file in your project workspace window under the linker script entry, but if you leave it empty MPLAB will use the default one for your processor.

Normally, it is unnecessary to tinker with the content of this file; if you would like to see what it looks like, the file for our processor can be found in the directory *MPASM Suite\LKR\18f27j13_g.lkr* under the Microchip installation directory. Explaining the contents and syntax of this file would make for a series of articles in their own right; fortunately for us, understanding the content is unnecessary at this stage.

Demonstration

Let's demonstrate creating an application using relocateable assembly.

Start MPLAB and select 'Project' followed by 'Project Wizard'. Click 'Next', and select our processor from the drop down list, PIC18F27J13, and then 'Next'. You are presented with a dialog that shows the toolchain, where you can change from assembly to other higher level languages. We are sticking with assembly, so we can just click 'Next'.

```
        list    p=18F27J13
        #include p18f27j13.inc

        extern task1,task2,service

        CONFIG XINST=OFF ; use normal instructions

    STARTUP CODE 0

        goto main
        nop
        nop
        nop
        goto service

    main:
        call task1
        call task2
        goto main
        end
```

Fig.2. Main.asm source listing

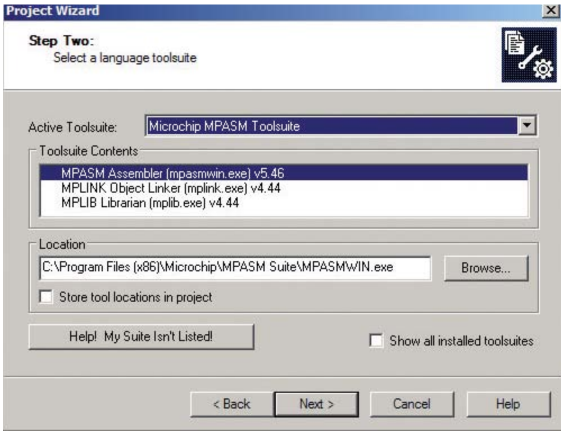


Fig.1. The MPLAB Toolsuite

However, before you do, take a look at the Toolsuite Contents, as shown in Fig.1. There are three components listed: Assembler, Object Linker and Librarian.

We've not mentioned the Librarian before. This is a utility that enables you to bundle multiple object files into a single library file, which you can add to your list of files to link together any other object file. It's really only a tool to simplify large projects, grouping together object files that are commonly used or are dependant on each other. While useful, it's not a tool we have used and we will not cover its use in this series of articles.

Returning to our project, click Next and at the next dialog enter a name for the project. Click 'Next', 'Next' and 'Finish'. At this point, we have created a project with no source files in it, but targeted to our processor of choice.

Let's create a new source file and add it to the project. Click on 'File' and 'Add New File to Project'. Navigate to the project directory and enter a file name of **main.asm**, then click 'Save'. Now enter the short program shown in Fig.2.

This simple program introduces some new concepts: the lack of an ORG directive (telling the assembler where your program should reside in memory) and two new directives, **STARTUP CODE 0** and **extern**. The extern keyword tells the assembler program that the subroutines task1,task2 and service do not exist in this file, and that it should not complain about their absence.

The word STARTUP is a user defined label (you could have typed any name,) and the keyword CODE indicates that the instructions that follow should be placed in the section called CODE. The optional numeric value at the end tells the linker that this particular section of CODE *must* start at FLASH location zero. This is necessary because this file contains the reset vector code. All other files containing CODE sections will not specify an absolute address, although they could, somewhat defeating the point!

Sections

Sections are areas of memory defined within the linker script. Typically, we have two sections, one for variables in RAM and one for code in FLASH, but it is possible to split available memory into smaller sections (perhaps avoiding an area where you want to store a bootloader, for example, or reserving an area for the reset vector)

When the linker examines all the object files that you want to glue together it will stick together all the different bits of code that have been marked for the same section.

Assemble the source file we have just created by right-clicking on the filename in the project window and selecting **Assemble**. Note that no errors are reported, even though there is clearly some code missing. What's going on here then?

In the project directory, two files will have been created – **main.lst** and **main.o. main.lst** is a text listing file showing the translation that the assembler has performed on this file.

The contents are shown in Fig.3. You can see that where the assembler has come across a reference to an external symbol it has not generated the complete instruction; the final part of the instruction (which defines the address) is left with question marks.

Even the reference to the 'main' label is not resolved; this is because the assembler simply does not bother to do a second pass of the file to correct this. Resolving addresses is a job left to the linker program, which we did not invoke.

The file **main.o** is the object file containing the binary data of our program. The assembler created this, leaving the unresolved addresses with zeros. Our 'program' has now been created; we could in theory store the source file away and just work with the **main.o** file, if we wished, adding source code modules to it to complete the missing functionality. For now though, let's leave files where they are.

```
000000 EF?? F???      00009        goto main
000004 0000           00010        nop
000006 0000           00011        nop
000008 0000           00012        nop
00000A EF?? F???      00013        goto service
                      00014
00000E                00015 main:
00000E EC?? F???      00016        call task1
000012 EC?? F???      00017        call task2
000016 EF?? F???      00018        goto main
                      00019        end
```

Fig.3. Main.lst assembler output listing

To prove the point about the linker, try building the project fully by selecting Project->Build all; the build process will fail at the link stage with the error 'could not find definition of symbol 'task1.'

So let's now complete the program by creating our missing subroutines in another source file. Click again on 'File' and then 'Add New File to Project'. Navigate to the project directory and enter a file name of **src2.asm**, then click 'Save'. Now enter the short program shown in Fig.4.

Notice how the program listing for **src2.asm** introduces a new keyword, **global**. This keyword tells the assembler that the three subroutine names should be made publicly available to any other file linked with it. Without marking a routine's name as global, its name is kept 'private'. This way, you can create two local subroutines in two different files with the same name without clashing when it comes to linking. Without this feature you will have to invent unique names for all your functions and variables, which would quickly become unmanageable!

The section name UDATA is where we can store our un-initialised RAM variables; to do so you specify a label – **counter** in this example – and the keyword res (for 'reserve') followed by the number of bytes.

```
    list     p=18F27J13
    #include p18f27j13.inc


MYVARS  UDATA

counter res 1
index   res 1

MY_SUBS CODE

    global task1,task2,service

service:
    retfie

task1:
    incf index
    return

task2:
    decf counter
    return

    end
```

Fig.4. The src.asm source listing

There are other predefined section names that allow us to place variables in specific RAM banks or access config memory spaces; we will look at those briefly next month.

Although the code for this month's article is shown in the figures, a complete workspace for this can also be downloaded from the magazine's website. As a program it doesn't do very much, but downloading it will save you some typing!

Conclusion

Although relocatable assembly does offer benefits over 'absolute', the author's preference is to use absolute assembly techniques. It's simpler to manage software development this way and the technique has scaled well to larger projects (the *CameraWatch2* project, for example, had twelve source files and generated 8KB of code.)

Which approach you take is probably a matter for personal taste. Relocatable assembly does have its place, however, when a project contains both C language files and some hand-coded assembly, but that is a subject for another day.

Next month

We start looking at one of the more complex features of the microcontroller next month – **Interrupts**. We discover why they are difficult to understand, how to get over this difficulty and demonstrate why they are so useful. Until then, it's time to extract the *PIC n' Mix* lab from packing cases!

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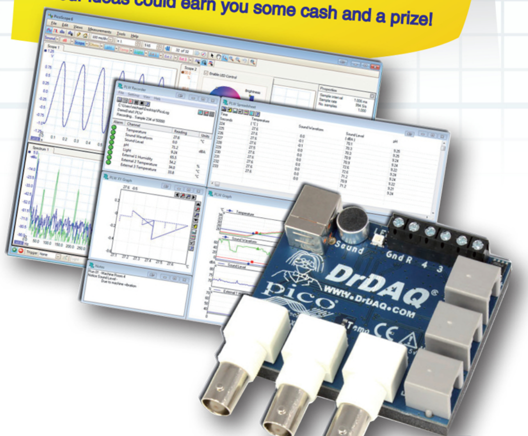


Capacitor ESR Checker – Health check

THIS simple checker shown in Fig.1 allows you to diagnose the health of an electrolytic capacitor. You can estimate the capacitor's equivalent series resistance (ESR), which is the best way of finding out whether it is fit for high performance applications, primarily in switch-mode power supplies (SMPS).

ESR checking shows up weakness in capacitors that otherwise look good. I built the checker because I was repairing an SMPS by replacing electrolytic capacitors, which are the most likely point of failure (visit **www.badcap.com** and web-search on 'capacitor plague').

Building and using

The checker is a standard 555-based astable oscillator, generating 1μs pulses at a pulse-repetition frequency of about 12kHz. The pulses have a duty cycle of about 80:1, so the test capacitor charges for 80µs, then discharges for 1µs at a current of 100mA. This is the maximum allowed for a CMOS 555 chip, and resistor R3 (68Ω) has to be selected to give 100mA.

To do this, connect a big capacitor (eg, 470μF) to the screw terminals, then connect an oscilloscope across R3 and measure the volt drop across it. Try different values for R3 until 100mA is obtained. Having a nice round number for the discharge current makes it easy to calculate ESR.

I just threw the checker together on stripboard, with a scrap of coax cable to plug it in to my old 20MHz 'scope. With a CMOS 555, it only draws 0.5mA from the battery. The important feature is the screw terminals. These give a very low contact resistance, which is important because a capacitor in good condition has a very low ESR, so no sloppy connections can be tolerated.

To use the checker, the test capacitor is connected to the terminals, making sure the polarity is correct. The battery is connected and the coax cable is plugged into the 'scope Y input. The 'scope settings go something like:

- Y input, AC coupled, 2V per division initially
- Trace position above screen centre
- Timebase, 0.2μs per division
- Triggering, AC, negative slope

Increase the Y-gain if necessary and adjust the triggering to get a good trace. After that, the assessment of the capacitor is by interpreting the trace.

Interpreting the trace

The best way to learn how to interpret the trace is to test a bunch of good and bad electrolytic capacitors in the range of values you are interested in. If you are repairing an SMPS, then you will

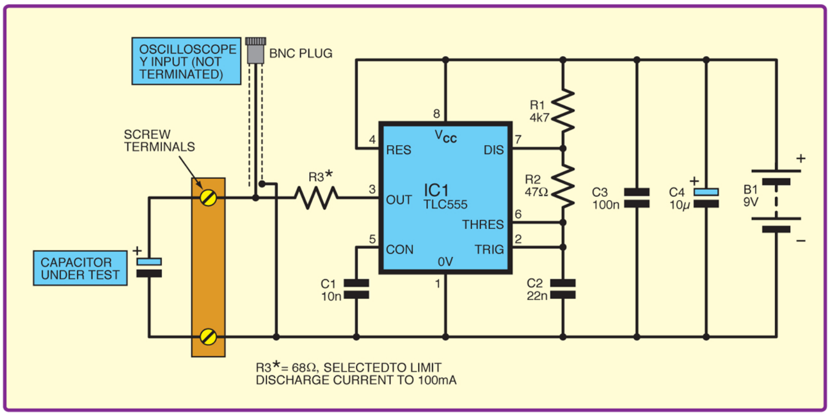


Fig.1. Electrolytic capacitor ESR checker circuit

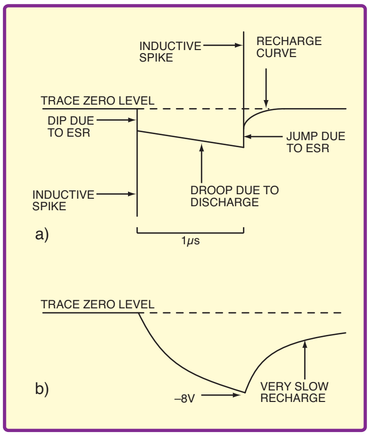


Fig.2. a) Typical waveform features seen on the oscilloscope trace; b) Waveform of a very bad capacitor – a 'very sick puppy'

soon have a couple of bad capacitors to look at. The illustration in Fig.2 shows the sort of thing to expect in an 'iffy' capacitor. The features shown are as follows.

ESR dip/jump

An ESR dip/jump is mostly what you are looking for. It should be small but distinct. Smaller is better. See the next section for typical values. For healthy capacitors of the same type, ESR decreases proportionately to the capacitance. That is, doubling the capacitance should halve the ESR.

Droop/recharge

In a healthy capacitor, droop should be very slight and recharge should be almost instantaneous. Use the well-known equation $CV = It$ to estimate the droop. A 100μF capacitor discharged at 100mA for 1μs should only droop by 1mV, which is probably not visible on the trace. Visible droop/recharge is a bad sign for the higher-valued capacitors, though it will be expected with values below about 47μF.

Spikes and resonance

I haven't drawn the resonances, these are little oscillations seen immediately after the inductive spikes. Spikes and resonance are caused by parasitic inductance within the cap. If you can't see them, it implies that the ESR is so bad it has damped them out. This is quite a sensitive test, but it is only qualitative.

Case history

In my Gateway 700G monitor SMPS there are 10 low-voltage capacitors, of which three showed visible bulges. However, after seven year of service, only two units (470μF and 220μF) still checked out as healthy with 'ESR-dips' of only 8mV and 16mV, implying ESRs of about 0.08Ω and 0.16Ω respectively. The rest had ESR-dips from 0.3V up to 1.5V.

Incidentally, most of these 10 capacitors were wired as parallel pairs, giving twice the likelihood of failure! A proper in-circuit ESR tester would not have been very helpful here.

My advice, from this, is simply to rip out all the low-voltage electrolytic capacitors and replace them (using 105°C-rated units, of course). This is not expensive and will save you from having to open up the SMPS at a later date to repeat the repair. Mount the replacement capacitors slightly proud of the PCB, so if the repair fails, they can be salvaged.

I also checked the capacitors for leakage, using a multimeter and a variable PSU. The 'sick puppy' shown in the illustration had a very respectable leakage of less than 10μA at rated voltage. Leakage measurement is always a good idea, but it only catches the most obvious cases. Obviously, there is no point doing an ESR test on a leaker.

Safety hints

Always discharge a capacitor before connecting it to the checker or measuring the leakage. When working on an SMPS, disconnect it from the mains and make sure the high-voltage capacitor is discharged. Don't repair an SMPS with recycled capacitors. An SMPS that is built into equipment may need a load; running it off-load may damage it (silly but true).

Walter Gray, Farnborough, Hampshire

Upgrade your kettle – On the boil

ELECTRIC kettles are simple, but they can be modernised. What steps could be taken to improve the reliability of them? The weakest part inside is the switch power button, or rather their electrodes. The main problem is that, the electrodes gradually burn up because of the relatively large currents they switch (on average 8A).

To make the electric contacting switching pair a more durable circuit, I suggest using a triac. These are available in either through-hole TO-220 or surface-mount packages; the BTA (BTB) triacs series is suitable for our AC switching application. It can switch the large current of the heater and since the triac gate current is much less, the switch electrodes should never burn out, making the electric kettle more durable.

Circuit details

This is really just a simple circuit (see Fig.3) for heating regulation, but with the usual control potentiometer replaced with a constant resistor (R1). By selecting the resistance of R1, you can select the power used. By experiment, I ended up with a value of 180kΩ.

The power will be a little less than the original rated level, but this is good for long-term durability. Nevertheless, the kettle will still boil almost as quickly as before.

To eliminate the direct current component, use a bi-directional diac (type DB3). Note that switch S2 is an internal thermal detector. It works as a 'disconnector', in case the kettle is switched on without water (all electric kettles have such a detector inside, on the heater). Resistor R1 is rated at 0.25W. The triac series must be BT type, then a letter (A or B, A – insulated, B – uninsulated), rated at 12A or 16A and 600V or 800V.

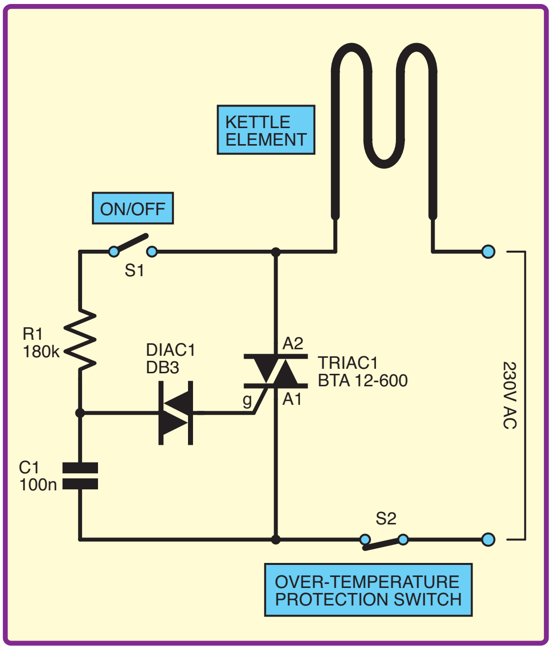


Fig.3. Kettle upgrade circuit

A heatsink for the triac is needed, but not too big so that it cannot be inserted into the kettle's handle (see my photo). The overwhelming majority of electric kettles have a hollow handle. As a rule, the handle is made of plastic, and although the triac heats up, it won't melt the handle because the triac's temperature is on average 50°C to 60°C. (My electric kettle (see photo) has been working for three year – with this adaptation – with no problems.)

The current through the switch is now about 10mA, instead of 8A. That's all, our kettle is upgraded.

Alexey Uskov, Vladivostok, Russia

Christmas LED Flasher – On display

THE circuit in Fig.4 is what I used to modulate (flash and dimming) two strips of blue LEDs, which were run from the 24V plug-top supply sold with one of these strips.

My first design, which worked last Christmas, used a 78L05 regulator to derive a 5V supply for a PIC chip that controlled the switching. However, on further investigation, it was found that this device was probably being used beyond its specified input voltage limit, as the plug-top supply was giving a lot more than 24V and had a large ripple on it (C1 charges to 36V!).

My design overcomes this problem by using a Zener diode (D2) to derive a supply for the chip. Diode D1 and capacitor C1 give a smoother supply to the Zener and to the chip since the current drawn by the chip is much less than that drawn by the LEDs. The main component of current to IC1 is determined by the base drive of transistor TR1, which is of the order of 8mA.

Transistor TR1 does the switching, driven by the PIC chip through R2/R4. With 1kΩ, a base current of about 4mA was expected, which was fine for a single set of 80 LEDs, but adding another 80 caused the value of Vce to rise significantly. A second 1kΩ was added in parallel, and with 160 blue LEDs the supply current was 0.4A with a Vce of 0.75V – well within the limits of the transistor (1A, 1W)

Switch S1 is used to turn the flashing off and run the LEDs continuously.

The PIC I used is one I had available, but any of the 12F series will do, because only a single output port and input port are used. Similarly, TR1 is a transistor that I had available, but any 1A *NPN* switching transistor could be used.

Clearly, four more switched outputs could be added, or even more with a 14-pin PIC chip to create fancier displays. However, a higher power-rated supply will be needed than the one used here (0.5A max).

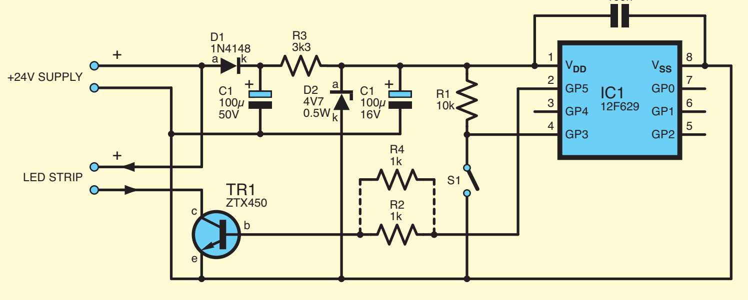
The software is straightforward, all it does is switch TR1 on and off with appropriate delays. Routines are created to give a 'dot' and a 'dash', which are then used to spell out any message desired.

Last, the unit was positioned indoors behind my TV, but no interference was noticed on it.

The listings for the PIC program can be downloaded from the *EPE* website at: **www.epemag.com**.

Ken Naylor, via email

Fig.4. Christmas LED Falsher circuit



Early effect and Early voltage

LAST month, we started looking at a question about bipolar transistor characteristics posted on *Chat Zone* by ***lost***.

Is the Early effect, which gives rise to h_{re} (dV_{be}/dV_{ce}), related to the Early voltage which gives rise to h_{oe} (dI_c/dV_{ce})?

The Early effect is named after the James Early (1922–2004), who first described it in a paper published in 1952.

Last month's article concentrated on a simplified description of the transistor physics underlying the Early effect. This month, we will show how we go from the physics view of the transistor to something we use more directly in circuit design. We will start with a brief recap of the physics.

Physics in brief

A bipolar transistor has two *PN* junctions in the same silicon crystal (via *NPN* or *PNP* structures). This is more than just two back-to-back diodes (which would never conduct) because the middle region (the transistor's base) is very thin.

If we forward bias the base-emitter junction into conduction, the majority carriers moving from the emitter become minority carriers in the base. With the base-collector reverse biased these (now) minority carriers can continue to the collector, attracted by the applied voltage.

The base is very thin, so the majority of the carriers are swept across into the collector before they have time to recombine. Any recombination that does occur forms the base current.

Ideally, changing the collector voltage (with a fixed base current) would not affect the collector current because the collector current is only related to the emitter-base charge flow (as described above), not the collector voltage. The collector would behave as a constant current source.

This results in transistor output characteristic curves, as shown in Fig.1(a). Once the transistor is in the active region, a constant base current sets a constant collector current (the characteristic curves are flat, and parallel to the axis).

In practice, changing the collector voltage changes the size of the depletion region, and thus the effective width of the conductive base region.

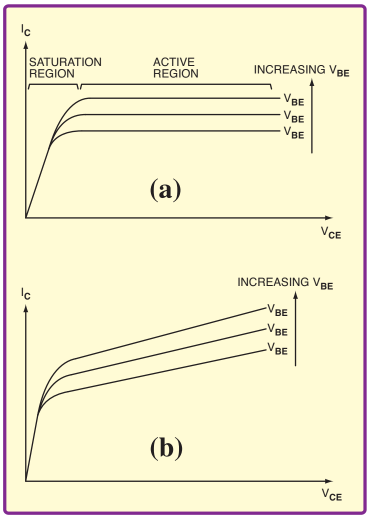


Fig.1. Transistor common-emitter output characteristics: (a) ideal case without Early effect, (b) with Early effect

This in turn affects the amount of time charge carriers have to recombine as they cross the base. As collector voltage is increased, the base narrows, recombination reduces and collector current increases. The transistor therefore behaves as an imperfect current source, that is one with finite, rather than infinite, internal impedance. The characteristic curves slope up, as shown in Fig.1(b), with the amount of slope corresponding to the transistors output resistance.

Circuit analysis

How do we use our understanding of transistor physics in circuit design? First, we will look at a simple example of circuit analysis to get a better feel for what we need. Two of the key principles of circuit analysis are known as Kirchoffs laws. One law states that the sum of currents *into* a junction in a circuit is zero (or *current in = current out*). The other states that the sum of voltages round any loop in a circuit is zero. Kirchoffs laws date from 1854, around 100 years before Early's work on the transistor, but they still form the basis of most circuit analysis today.

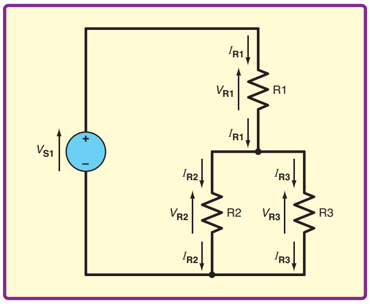


Fig.2. Example circuit for discussion of circuit analysis (see text)

We can use these laws to form equations relating to the circuit. For example, for the circuit in Fig.2 the Current Law gives us (using current in = current out):

$$I_{R1} = I_{R2} + I_{R3}$$

and the Voltage Law gives us

$$V_{S1} = V_{R1} + V_{R2}$$
$$V_{S1} = V_{R1} + V_{R3}$$

and so

$$V_{R2} = V_{R3}$$

Kirchoffs laws deal with either voltage or current on their own. To fully analyse a circuit we need to know the relationships between currents and voltages in the circuit. These relationships are described by the characteristic equations of each component. For example, a resistor's characteristic equation is:

$$V = IR$$

which many readers will recognise as Ohm's law. So, for Fig.2 we can write, for example:

$$V_{R1} = I_{R1}R_1$$

Ohm's laws, and hence the characteristic equation for the resistor, was first obtained experimentally by Georg Ohm in the 1820s. It can also be derived from the fundamental physics of conductors, although historically this happened much later. For a real resistor, Ohm's law is an approximation, the resistance may actually change with applied voltage, and it will change with temperature, including that caused by self-heating of the resistor.

Furthermore, resistors generate electrical noise, but Ohm's laws only applies to the average current. The mathematical way in which we choose to represent a component

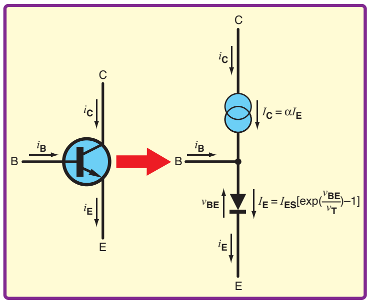


Fig.3. Simple model of a transistor (without Early effect) based on our discussion of transistor operation (see text)

is referred to as the model of that component.

Most of the time, for resistive components we use in circuits, we can simply use $V = IR$ in circuit analysis. If we choose to include other factors in our calculations (and do so correctly) we get a more accurate results at the expense of more difficulty, and complexity. For manual calculation, too much complexity may make the problem error-prone, or even intractable. For computer-based analysis (circuit simulation) run times will increase with more complex models. As always in engineering there are compromises, in this case between accuracy and complexity.

In the resistor characteristic equation $V = IR$, the 'R' (the resistance) is referred to in general terms as a parameter (or model parameter). All component characteristic equations will have one or more parameters. We can analyse a circuit algebraically using symbols for the parameters (eg, R1, R2 etc for the resistors), but if we need to know actual voltages and currents we have to obtain the specific parameter values for every component.

Shockley ideal

In order to include semiconductor components, such as diodes and transistors, in circuit analysis we need a model; that is the characteristic equations for general analysis, and actual parameter values for specific calculations. Looking at the diode first, we can use an understanding of semiconductor physics (somewhat deeper than that given in these articles) to derive a characteristic equation for a diode. For an idealised case we get the following:

$$I = I_s\left[\exp\left(\frac{V}{V_T}\right) - 1\right],$$

which is known as the Shockley ideal diode equation.

V_T is called the thermal voltage. It is about 26mV at room temperature and is given by kT/e, where T is the junction temperature (in Kelvin) and e and k are physical constants, the charge on the electron and Boltzman's constant respectively. The key parameter for individual diodes is I_S – the reverse saturation current – which is around 10^{-12}A for silicon diodes.

The situation with transistors is slightly more complex because they have three terminals, so there is more than one voltage and current associated with them. We can extend the basic ideas of Kirchoff's laws and component characteristic equations to handle components having more than two terminals, but it is often convenient to represent more complex devices such as transistors as an *equivalent circuit model* comprising a few basic two-terminal components.

Transistor model

Based on our preceding discussion, and for the moment ignoring the Early effect, we can develop an equivalent circuit model for the transistor. We described the transistor as having a *forward-biased PN* junction between base and emitter, with the collector acting as an ideal current source. This indicates that our equivalent circuit should contain a diode (from base to emitter) and a current source connected to the collector. A suitable circuit, based on this argument, is shown in Fig.3.

We also described the fact that most of the charge carriers cross the base into the collector, although some recombine, thus the current in the collector will be slightly less than the current in the emitter (ie, the diode current in Fig.3). We can set the current source value as αI_E, where I_E is the emitter/diode current and α is a value less than 1 (0.99 would be typical). The diode current can be found using the Shockley diode equation, and we can find the actual value as long as we know the temperature and the reverse saturation current of the transistor's base-emitter junction (I_{ES}).

The model in Fig.3 is highly simplified, we have already mentioned the lack of the Early effect, but there are other things too. The model will not work if we forward bias the base-collector junction, so it is limited in the range and polarity of transistor voltages it can handle. In theory, a bipolar transistor could be completely symmetrical, so that we could swap round the emitter and collector and it would behave in exactly the same way. In practice, the physical structure is optimised for performance and is not symmetrical, but reverse operation is still possible.

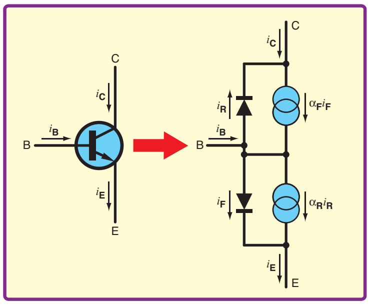


Fig.4. The classic Ebers-Moll transistor model is a complete version of the model in Fig.3

Ebers-Moll model

A more comprehensive model needs to take account of the transistor's (partial) symmetry and leads to the equivalent circuit shown in Fig.4. This is called the Ebers-Moll model, named after Jewell James Ebers and John Louis Moll who published it in 1954. It should be reasonably clear how the Ebers-Moll model relates to Fig.3.

In our discussion on the Early effect we noted that the collector current increases proportional to the collector-emitter voltage. This can be seen in Fig.1(b) where the characteristics are straight lines sloping up in proportion to V_{CE}. The Early effect adds additional current to that predicted by the constant current model of collector current (Fig.1(b) and Fig.3). If the constant-current model collector current is i_{Const} we can write the current with the Early effect taken into account as:

$$i_{Early} = i_{Const}\left(1 + k_E v_{CE}\right)$$

Where the '1' in the equation ensures that the constant-current model current is included and k_E is a constant of proportionality which determines how much extra current is added due to the applied collect-emitter voltage (v_{CE}).

In fact, we do not use the symbol k_E for the Early effect, the constant of

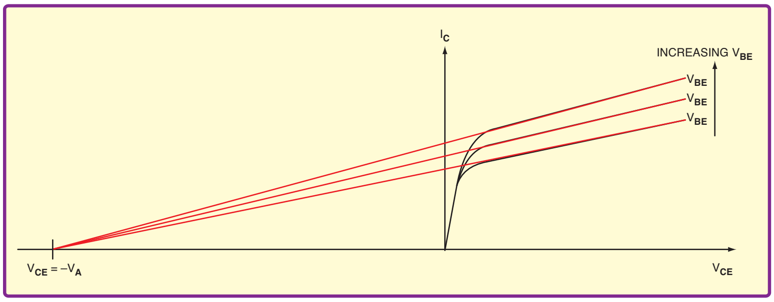


Fig.5. The Early voltage

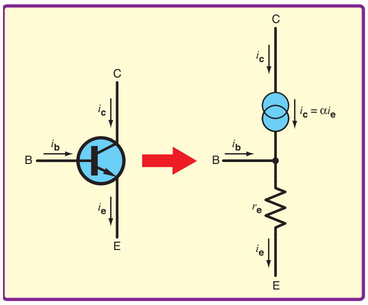


Fig.6. Small signal version of the model in Fig.3. Note that value of r_e changes with different bias conditions

proportionality is actually $1/V_A$ (one over the Early voltage). As we saw last month, the Early voltage can be found by extrapolating the collector current characteristics, as shown in Fig.5. We can modify the diode current equation in the model in Fig.3 to take account of the Early effect as follows:

$$I = I_{ES}\left[\exp\left(\frac{v_{BE}}{V_T}\right) - 1\right]\left(1 + \frac{v_{CE}}{V_A}\right)$$

The Ebbers-Moll model can also be modified to take account of the Early effect, although the equations are more complex due to the fact that the model takes account of more of the transistor's behaviour.

If we are analysing a transistor circuit in which the base-emitter stays forward biased and the base-collector junction stays reverse biased, the circuit shown in Fig.3 will be sufficient and we do not have to use the full Ebers-Moll model.

h-parameter model

Readers may have noticed that we have not yet mentioned h_{re} and h_{oe} from lost's questions. These are also model parameters, but of a different type of model of the transistor, known as the *h*-parameter model, in which the *h* stands for 'hybrid', indicating the parameters are a mixture of quantities. The models in Fig.2 and Fig.3 are useful for calculations such as biasing setup – basically for DC conditions.

However, when we need to deal with AC signals, such as when trying to calculate the gain of an amplifier, the exponential diode equation makes the calculation process very difficult. Thus, we use different models in such situations, and the *h*-parameter model is one example of such models.

When dealing with AC signals, it is easier to use models in which all the equations are linear. A linear equation, as the name suggests, produces a straight line on a graph when you plot it.

The diode equation is not linear, but if we take just a small section of the diode's voltage-current characteristic curve it is a reasonable approximation of a straight line. This relates directly to how we design transistor circuits, such as amplifiers – we set a bias point (or operating point) which determines the circuit's voltages and currents with no signal present and the signal causes a small variation about this point.

The linearised AC circuit models are called small-signal models. The parameter values are only correct at a particular bias point, although the general model structure (and hence algebraic manipulation of equations) can be used over a wide range of bias points, as long as the fundamental operation of the transistor does not change. DC voltages and currents are ignored in small signal calculations, except to obtain the correct model parameter values.

We can easily convert our simple model in Fig.3 to a small-signal model by replacing the diode with a resistor, referred to as the 'emitter resistance'. This model is known as the *T* model of the transistor and is shown in Fig.6. The emitter resistor value is given by:

$$r_e = \frac{V_T}{I_E}$$

Where V_T is the thermal voltage (defined earlier) and I_E is the bias current in the emitter.

The *h*-parameter model for a transistor in common-emitter configuration is shown in Fig.7. The equivalent circuit structure is different from the *T* model, but we find that there is still a resistor (h_{ie}) in the base-to-emitter path (the input resistance) and a current source ($h_{fe}i_b$) between collector and emitter (equal to the forward gain, h_{fe}, times the base current). The *e*'s that occur in the parameter subscripts indicate the model is for common-emitter configuration.

The *h*-parameter model accounts for the Early effect with an output resistor of value $1/h_{oe}$ (h_{oe} is the output conductance), as shown in Fig.7. We can find the value of h_{oe} by differentiating the Shockley diode equation (shown above) at a fixed V_{BE} (the bias voltage). This is the slope of the output characteristic in Fig.1(b) and Fig.5; in the ideal case (Fig.1(a)) the slope (and h_{oe}) is zero. We get:

$$h_{oe} = \frac{I_C}{V_A + V_{CE}} \approx \frac{I_C}{V_A}$$

The approximate form assumes V_A (typically 100V) is much larger than V_{CE} (typically a few volts). I_C is the DC collector (bias) current and V_A is the Early voltage.

Summary

So far, in these articles we have concentrated on the impact of the Early effect on the collector current and hence the transistor's output conductance. The Early effect (base width modulation) also causes feedback within the transistor. This effect is far smaller in magnitude than that on output conductance. Furthermore, as noted in Early's original paper, it is not the only process which causes feedback within the transistor.

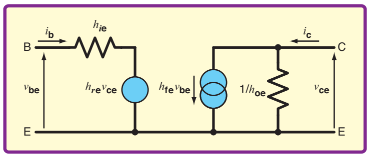


Fig.7. The h-parameter model of the bipolar transistor in common emitter configuration

The Early effect means that increasing collector-emitter voltage decreases the base width, hence the emitter resistance (as depicted in Fig.6) decreases. Thus, for a fixed emitter current, less voltage is required across the base-emitter junction. Another way to describe this is that a lower base-emitter voltage is required to maintain the same emitter current.

The *h*-parameter model accounts for this aspect of the Early effect (and other feedback mechanisms) with the voltage source $h_{re}v_{ce}$. As v_{ce} increases, the voltage of this source increases, reducing the base-emitter voltage required to maintain a specific base current (due to the reduced voltage across the input resistance h_{ie}).

The amount of feedback is determined by the parameter h_{re}, the reverse voltage gain. h_{re} is often ignored in circuit analysis because it has a very small effect, however, it is important in some situations, for example RF amplifiers.

Trade-off

The preceding discussion illustrates the process of going from a physics-based understanding of a semiconductor device to an equivalent circuit model which can be used in hand calculations, or simulations, for circuit design. There is no single correct model for a transistor; the choice of model depends on a trade-off between accuracy and complexity and its suitability for the task in hand.

It is not always necessary to have a full understanding of the physics to use a model, the model parameters can be obtained empirically by making appropriate measurements on real devices and curve-fitting data to the model.

Reference

Early, JM, Effects of Space-Charge Layer Widening in Junction Transistors, *Proceedings of the IRE*, vol.40, no.11, pp.1401-1406, Nov. 1952.

By Robert Penfold

Passive light change detector

THE subject of optical sensors was covered in the previous *Interface* article, and we start this month by considering a further sensor of this type. A passive light-change detector is a simple but effective way of sensing some types of object. This type of sensor is not greatly affected by the ambient light level, and it does not matter if the light level changes substantially, provided it does so gradually.

The only proviso is that the light level must remain within the operating range of the photocell. In other words, it must not be so dark that minor variations in the light level produce no significant change in the output level, or so bright that the photocell becomes saturated and again falls to respond to small variations in the light level.

Quick change

Rather than using a DC-coupled circuit, as in the simple light detector featured in the previous *Interface* article, a light change detector uses AC coupling. A fast change will produce a signal that is coupled from the sensing device to the main circuit, and an output pulse will be produced. A slow change will be coupled to the main circuit very inefficiently, and will fail to trigger the unit.

The cut-off frequency is clearly crucial in a circuit of this type, since setting it too high will prevent anything but the fastest of changes from triggering the circuit. Setting the cut-off frequency too low will result in ordinary variations in the background light level triggering the circuit.

For this type of unit to work well there must be a reasonably large difference in the fastest normal change in the ambient light level and the speed of change produced by the detected object. When the sun goes behind a cloud or emerges from behind one there is a fairly rapid change in light level, but it is far from instantaneous.

When someone passes in front of a photocell, or perhaps a model racing car passes through its line of sight, the change in light level will probably be relatively small, but it will be much more rapid. This difference in speed should be sufficient to enable good reliability to be obtained.

It is only fair to point out this type of detector might not be one hundred percent reliable in all situations, even if a well chosen cut-off frequency is used. Something like a flash of lightning or a light being switched on or off will produce a fast change in light level that will activate the unit. This may or may not be important, depending on the exact application and way the system will be used. Where this might cause problems it would obviously be better to use a different type of sensor.

Getting a buzz

Another point to bear in mind is that mains powered lighting is sometimes amplitude modulated at 100Hz. The modulation is at 100Hz rather than 50Hz because the intensity peaks as each half cycle reaches its maximum level, and there are one hundred half cycles per second. This is something that is more of a problem with old style filament bulbs than it is with most modern 'eco' bulbs. Anyway, with a sensor of this type it is possible that the variations would be sufficient to produce a pulse train at the output, thus preventing the unit from working in a worthwhile fashion. Again, this may or may not be a problem, depending on the way in which the unit will be used, and it is a hitch that can occur with some other types of optical sensor. Where it is likely to be troublesome, steps must be taken to prevent the sensor from receiving significant levels of mains modulated light, or using a different type of sensor might be a better option.

Sensor circuit

The circuit diagram for a simple AC-coupled passive optical sensor is shown in Fig.1. Phototransistor TR1 is the sensing element, and resistor R1 is its load resistor. In dark conditions, the collector (c) to emitter (e) leakage current of TR1 is at the very low levels normally associated with silicon transistors.

Higher light levels cause higher leakage currents to flow, and the voltage at the collector of TR1 falls accordingly. Variations in the received light level are, therefore, converted into changes in the potential at the collector of TR1.

These voltage changes are coupled via capacitor C2 to the input of a simple common-emitter amplifier based on TR2, and this amplifies them by over one hundred times. The amplified signal is coupled by C2 to the input of a dual voltage detector, or 'window discriminator' as this type of circuit is sometimes called.

It is based on a dual operational amplifier (IC1), but in this circuit both amplifiers are used as voltage comparators. The inverting input of IC1b and the non-inverting input of IC1a are biased to half the supply potential by resistors R4 and R5.

However, the output signal from the amplifier (TR2) is coupled (via C3) to these inputs, and the voltage here can be varied up or down by the signal from the amplifier. The potential divider chain formed by R6 to R8 holds the non-inverting input of IC1b at one third of the supply potential, and the inverting input of IC1a at two thirds of the supply potential.

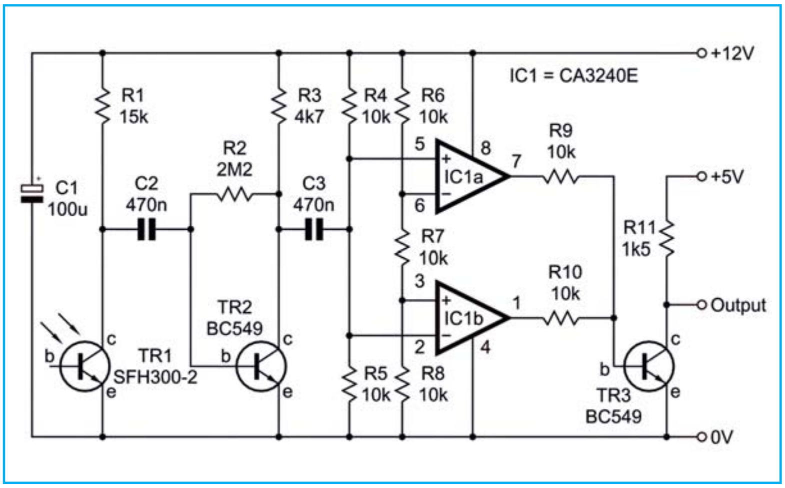


Fig.1. The circuit for an optical sensor that detects changes in light level rather than triggering at a particular light level. The dual operational amplifier (IC1) is used here as two voltage comparators

As things stand, the inverting inputs of both operational amplifiers are at higher voltages than their non-inverting inputs, and the outputs of both devices therefore go low (0V). However, if the signal from the amplifier is strong enough, it will either take the non-inverting input of IC1a above the reference level at its inverting input, or it will take the inverting input of IC1b below the reference level at its non-inverting input.

This causes the output of one or other of the operational amplifiers to go high (about +10V), and bias TR3 into conduction due to the base (b) current that flows through R9 or R10. The normally high output of TR3 then goes low, but due to the AC coupling used in the circuit things rapidly return to their standby states. However, a short output pulse from the circuit is normally all that is needed. The point of using a dual voltage detector is that it does not matter whether there is a rise or a fall in the light level received by TR1. If it is of sufficient amplitude it will be detected immediately by one or other of the voltage comparators.

Stepping down

The CA3240E op amp used for IC1 will not operate properly from a supply voltage as low as 5V, and a 12V supply is therefore used for the main circuit. Any supply voltage from about 9V to 12V will suffice. Transistor TR3 is used as a simple common-emitter switch that is operated from a 5V supply, and it provides an output signal that will drive most types of 5V logic device. It should be noted that the CA3240E has a PMOS input stage, and that it therefore requires the usual anti-static handling precautions.

Practically any normal phototransistor for use in the visible-light spectrum should suffice for TR1. No connection is made to its base terminal, and devices that do not have the base connection accessible are therefore all right for use in this circuit.

A photodiode is not really suitable for use in this circuit as the sensitivity of these components is too low to give worthwhile results. A photo-resistor would probably work quite well, but some of these components are quite slow in operation and might not give good results. Any high-gain silicon *NPN* transistors can be used for TR2 and TR3.

The cut-off frequency of the circuit is governed by the values of coupling capacitors C1 and C2. They provide a simple form of highpass filtering in conjunction with the input impedances of TR2 and the dual voltage detector circuit. Using lower values would give better immunity to spurious activation by slow changes in the light level, but might reduce the sensitivity of the circuit to normal triggering.

It might be worthwhile experimenting with the values of these two components, but good results should be obtained using the specified values. This interface can be used in conjunction with a tube or a lens in order to increase its sensitivity and (or) directivity, as described in the previous *Interface* article.

Interrupting

When reading data from a computer add-on there are two basic approaches, which are termed 'polling' and 'interrupts'. Polling is where the add-on device is checked periodically to see if any fresh data is available, and in a real-world application the device often has to be checked at a fairly high frequency in order to obtain good results. Polling is relatively simple to implement, but it is inefficient, there tends to be numerous read operations that produce no fresh data.

Using interrupts is much better, and the basic idea is to have the interface send new data as soon as it is available. This generates an interrupt at the CPU, and the new data is read and dealt with as soon as possible.

There might be a very short delay while an interrupt with a higher priority is dealt with, but with this method any delay between new data becoming available and being read should be very small. It also avoids having numerous read operations that produce no new data. The normal drawback with interrupts is that it is relatively difficult to implement in the software, and some low-level programming is often involved.

However, this is not the case when using a virtual serial input port of the type featured in previous *Interface* articles. The add-on circuit simply has to trigger the appropriate input of the interface, and the new data will then be sent to the computer, where it will generate an interrupt.

This interrupt will be dealt with by the Visual BASIC SerialPort component, and the new data will be read by the application program. There is no need for the programmer to get involved with the intricacies of interrupts, because this is all handled by Visual BASIC.

It would be possible to implement a polling system with the aid of an output port, but it is difficult to envisage a situation where this would be the best way of doing things. It is better to design add-ons to take advantage of the easy interrupts made possible by this method of interfacing.

Multiple sensors

With only one optical interface driving a virtual serial port interface there is no need to bother with the data input lines at all. The interface merely has to signal to the software in the computer that the interface has been activated, and the software then takes appropriate action, such as incrementing a counter by one, or starting a timer. It is merely necessary to connect the output of the optical sensor to the WR (Write) input of the interface chip or module.

A byte of data is sent to the computer each time the sensor is activated, and an interrupt is generated. Although it is of no relevance, the byte of data from the port should still be read into a variable so that the buffer from the serial port is cleared.

Matters are complicated slightly if more than one sensor is used with a virtual serial input port. Each sensor's output must feed a separate input of the input port. The software can then read bytes of data from the port and use the normal bitwise ANDing process to determine which input line or lines have been activated.

However, every sensor in the system must also be able to drive the WR input of the virtual serial interface so that a byte of data is transmitted whenever one of the sensors is triggered. This simply requires the WR input to be driven from the outputs via an OR or NOR gate.

Something as basic as the four-input NOR gate, as depicted in Fig.2, will suffice. Although shown as a four-input gate in Fig.2, the circuit can have anything from two to eight inputs by using the appropriate number of resistor/diode sections at the input. The outputs driving the circuit should be low under standby conditions, and should pulse high when active. An inverter should be added ahead of an input if the output driving it operates with the opposite sense.

In theory, a short delay is needed in order to ensure that valid data is present on the data bus before it is transmitted. In practice, this is not always necessary, but the relative slowness of a simple gate of this type should ensure the data lines have time to stabilise before the data is transmitted.

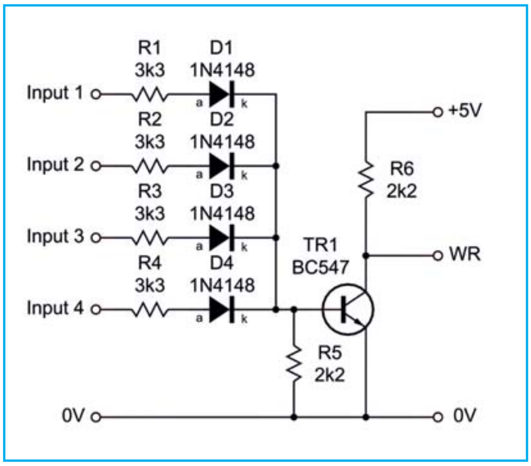


Fig.2. The circuit for a simple four-input NOR gate. There can be anything from two to eight inputs if the appropriate number of diode/resistor sections are used at the input

Max's Cool Beans

By Max The Magnificent

I'm sure you are expecting an electronics-related column, but I have a bit of a surprise for you. I am a man of many talents. Unfortunately, these talents do not include juggling or riding the unicycle, although I'm working on both, but that's a story for another day. The thing is that my current hobby project is to build a mosaic. I can no longer recall where I got this idea. All I remember is that something made me think 'I want to create a mosaic.' Of course, the first problem was to decide on a subject for my masterpiece. As fate would have it, around that time I saw a replay of the *Doctor Who* episode (which originally aired in 2010) where the Doctor goes back in time and meets Vincent van Gogh, and I thought to myself 'Ah Ha! I'll create a mosaic of Vincent's *The Starry Night*!'

This is actually proving to be a lot more work than I had ever envisaged, but a lot of that is self-inflicted because I simply cannot stop myself from over-engineering things. As you will doubtless recall, *The Starry Night* involves a magnificent view of the night sky. At the bottom of the picture are some rolling hills, and there's a big tree in the foreground.

Starry, starry-eyed Max

My first step was to search the Internet for an image of this picture, which is when I discovered that many people have created their own interpretations. I started by printing out a small (8-inch wide) copy of the original, along with another version that had a tree I liked better. Next, I got some tracing paper and traced the main features. I then scanned this tracing into my computer, added a grid of tiny squares (where each square would eventually correspond to an inch in the real world), printed the result out again, and then hand-scaled everything up to full size.

Now, this is where things started to become a tad complicated, because I decided I wanted to give my creation some 'depth.' The way in which I did this was to use layer upon layer of hardboard to represent the mountains in the mid-ground and the tree in the foreground.

For a number of reasons, this was actually a little trickier than you might suppose. For example, it may appear as though the tree is completely separated from the main board. In reality, however, layers of hardboard forming the mountains also go up behind the tree. Starting with the layer nearest to the observer, each layer behind comes in by another 1/8-in, thereby giving the tree its free-standing appearance. The result is incredibly strong.

Truth to tell, I became a little over-enthusiastic with the tree. Originally, I was planning to have only a couple of layers, but it looked so good that I kept on adding more and more levels, with the result that the very front of the tree ended up higher than the frame. My initial reaction was to increase the depth of the frame, but then I realized that having the tree growing 'through' the frame would increase the sense of 'depth.' Of course, this introduced additional complications – if you look closely at the photo opposite, you can see a couple of areas where I had to chisel the frame to match the different levels of the tree. Suffice to say, the end result – which we see here sitting on my kitchen table – actually looks rather good in its own right.

But wait, there's more, because now we come to the topic of the tiles. Originally, I was thinking of simply purchasing a bunch of different colored ceramic tiles. I vaguely thought that is might be possible to get them already chopped up, but as a worse-case I was prepared to do this myself. The more I thought about this, however, the more I came to realise that using flat, single colour tiles would not give the optimal effect. What I need is some way to make my tiles evoke van Gogh's brush strokes.

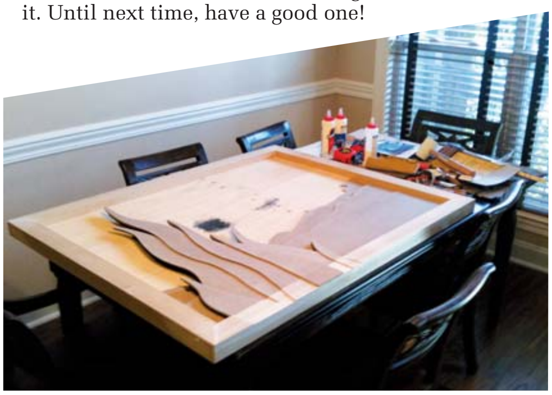
On the tiles

This is a story that grows in the telling, but the bottom line is that I've decided to make and glaze the tiles myself. To this end, a couple of weeks ago I purchased a small kiln, which involved all sorts of additional problems like (a) having to have a special power supply routed to the back porch, and (b) convincing my wife that all the neighbours would be jealous of us for having a kiln on our back porch (grin).

I've now got a hundred or so test tiles bisque-fired, which means they are ready to be glazed and then re-fired. I've also got a bunch of different glazes. The main thing I've discovered is that working with glazes is not like working with pigments. If you mix yellow and blue paints, for example, you stand a batting chance of ending up with a greenish hue. The same is not true of glazes. When you are working with high-temperature glazes, you are talking about liquid glass, at which point the minerals in the glazes can undergo all sorts of strange chemical reactions.

So, you can see why completing my mosaic is going to take a long, long time. However, I think the end result is going to be spectacular. The only problem now is that this could take a couple of years, which means that by the time I finish it I will no longer have the strength to lift it.

Oh well, we will cross that bridge when we come to it. Until next time, have a good one!



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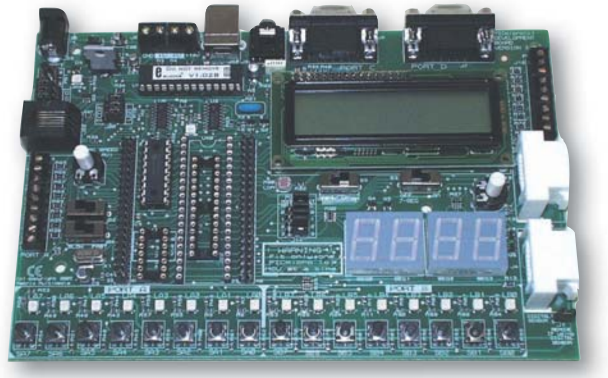

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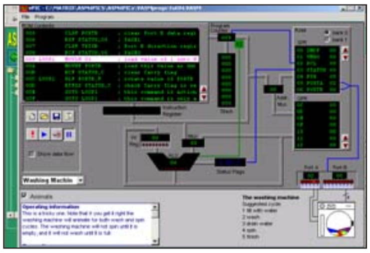

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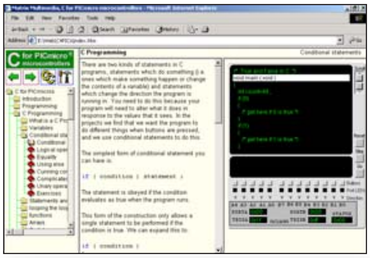

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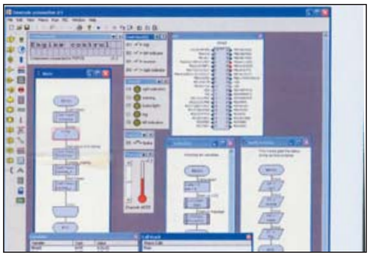

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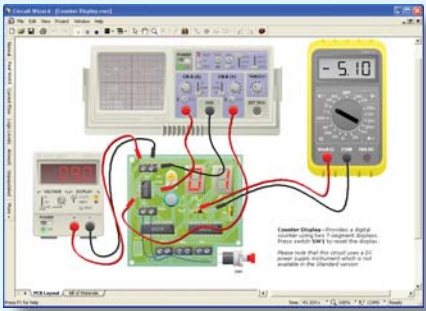

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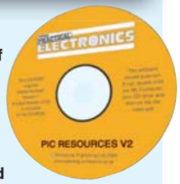

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NET WORK

by Alan Winstanley

Net boost

The Billion 3100SN Wireless-N access point fits into a mains socket and can extend Wi-Fi coverage to avoid wireless deadspots. After fitting the mains socket adaptor set, the assembly is slightly brittle overall

LAST month, I tried out a TP-Link Wireless Range Extender TL-WA830RE, a cheap and cheerful device that promised to 'extend existing wireless coverage indoors, in as little as a few seconds at a push of a button'.

In actual fact, last month's article contained some hectic last-minute rewrites because my experiences with this range extender were being shaped as quickly as I could write the copy. After I persevered with the network and range extender setup, which had to be done manually – no push-button setup for me, sadly! – ultimately my quest to extend my wireless network took me elsewhere.

I showed last month how inSSIDer software (free from **metageek.net**) could show neighbouring Wi-Fi networks, and early on I changed channel to avoid conflicting with them. The TP-Link Range Extender proved quite erratic in use, and various peripherals soon followed suit: a Wi-Fi PC kept falling off the network and reconnecting every few seconds, oscillating madly. Worse, InSSIDer showed how the range extender signal was dropping out frequently and the device needed rebooting regularly. Plenty of user testimonials online say that this budget-price unit worked for them, but my own experiences were very mixed and after more rebooting I disconnected this range extender altogether. The wireless PC then re-connected through the router's weaker signal, but performance was less sprightly again.

Meow...meow

Sometimes, running a home Wi-Fi network is a bit like herding cats. There is plenty of scope for introducing networking conflicts that can cause frustrating problems. For example, incompatible security standards on legacy wireless adaptors, or interference from wireless devices or electrical apparatus. The whole industry probably over-promises on the experience that Wi-Fi delivers (see September 2012 *Net Work*, when I trialled a typical Wi-Fi security camera) and I remain skeptical about budget-priced wireless products, whether they are routers, wireless cameras or even so-called 'range extenders'. Eventually though, things usually settle down for a while and you can start to relax and enjoy the benefits of wireless networking until something goes wrong again.

When experimenting with Wi-Fi channels I found that my Humax Fox T2 Freeview recorder disappeared off the network completely. Nothing to do with the TP-Link range extender that time, but the helpful Hummy.TV forum suggested that the Humax box may ignore everything below channel 5 (which is precisely where I was – see screenshot on p.72, November issue). After upgrading its firmware, resetting and rebooting everything in sight, followed by hours of joyless trial and error I changed the Wi-Fi to channel 13 and the TV box snapped into life immediately, working better than ever before, for a time.

More adaptable

Aiming to improve my wireless network coverage around the home, next on my agenda was the Billion BiPAC 3100SN Wireless-N wall plug Ethernet access point. Coupled to my Billion 7800N router, would I have more success second time around? The easiest way of understanding its operation is to think of a Homeplug adaptor (Ethernet through the mains), but using Wi-Fi instead of mains electricity to carry network traffic. Like a large mains-adaptor bristling with Wi-Fi aerials, the BiPAC 3100SN can act as a wireless bridge that links one network to another one, or connect network peripherals through its Ethernet socket, or it can function as a repeater to extend the range of an existing network.

Like the TP-Link TL-WA830RE before it, it's necessary to configure the device by connecting it with an Ethernet cable (supplied) to a spare laptop or PC. Critically, the PC's IP address has to be changed to a static IP temporarily to allow communications with the access point. Details of how to do this are fully explained on the User CDROM, which, I was pleased to see, covered all versions of Microsoft Windows from Windows 95 up to Windows 7: no need to hunt online for an FAQ here!

After plugging the AP into the mains, by typing the access point's IP address into my web browser, the Billion's setup pages appeared – similar style to the Billion router's – and my wireless network's details could easily be input. I changed just a few options (choosing 'Repeater' mode for the Wireless Distribution Service), and ensured that my own wireless network (and not the neighbouring ones that it also detected) was selected from the pick-list.

The repeater sprang into life without a murmur, displaying two LEDs. It proved best to reboot the router and let the system settle down; and my wireless devices all started up without a hitch. Even the Humax T2 claimed a connection speed of 135.0Mbps, which was a five-fold improvement. The setup took less than 30 minutes in all. After changing the laptop's IP address back to dynamic mode, I ran inSSider to check wireless performance, which confirmed that the Billion access point repeater was operating as expected.

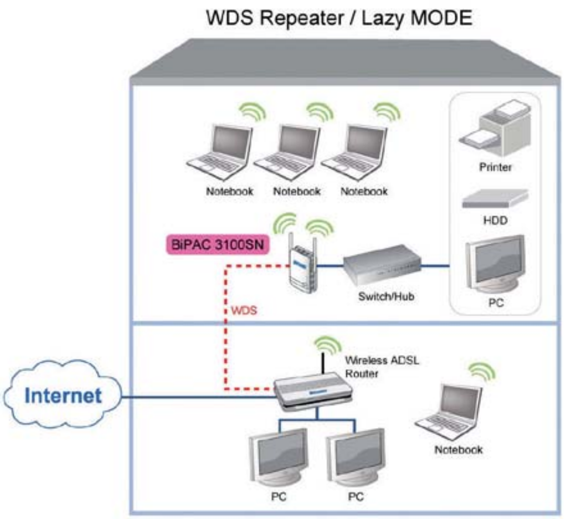
Fairly fragile

Of course, this mains-adaptor style unit takes up a spare mains outlet for good. Like the Billion 7800N router, it has a well-ventilated plastic case intended for constant use. Power consumption is rated at 25W, implying a running cost of less than £2 a month.

In a manner similar to some international mains adaptors, a separate plastic moulding clips on to the case to adapt it for British 13A mains sockets (or your country's style). It is quite a brittle arrangement that is not very robust. Indeed, the manufacturer warns users not to fiddle with the socket clip too much or damage may be caused.

I would add that the design is not 100% foolproof either: I found that it's possible to use a well-aimed fingernail behind the box to unclip it from the 3-pin moulding when it's still plugged into the mains, leaving live mains terminals exposed in the socket. Some international mains adapters have the same design problem, coming apart all too readily and exposing live terminal pins. Used with care, the arrangement should be adequate, but it is probably best to locate it out of harm's way, and even consider supergluing the Billion's moulding together for better security.

Overall, the Billion 3100SN Wireless-N repeater was easy to set up and has been working solidly ever since. There are plenty of menu options available for expert users to dabble with, so whether you want to bridge a group of networked devices to another group, or simply boost the coverage of your home network, this device should be on your short-list. The Billion 3100SN typically costs around £50, but why not try the Amazon price alert website **www.camelcamcamel.com** (UK) to monitor the prices and maybe snap up a bargain when prices waver.



A Billion BiPAC 3100SN plug-in access point (AP) in repeater mode, to extend Wi-Fi coverage around the home. Multiple APs can be used in bridge mode, acting as wireless links for network devices. (*Courtesy of Billion Electric Co Ltd*)

Amazon's Fire sale

It is reported that twenty-two percent of American adults own a tablet device. 25 October saw the launch, a year after its original American release, of the updated Kindle Fire from Amazon (as mentioned in December 2011 *Net Work*). It is a 7-inch diagonal touchscreen colour ebook reader and tablet locked into Amazon's way of doing things. The colour Fire starts at £129 and the Fire HD is £159.

The screen uses super-tough Gorilla glass to withstand rough handling. It includes Amazon's Silk web browser, which fetches from Amazon's cache of web content hosted on the Amazon cloud, thereby promising faster surfing. The email client claims to be compatible with AOL, Gmail, Hotmail, Exchange and more, and direct support for Twitter and Facebook is offered. Movies from Lovefilm can be streamed directly and 802.11n wireless is provided. Finally, up to nine hours of battery life is claimed.

Zamzar's free file conversion service can handle a multitude of filetypes, and will email you a download link within an hour or two

The Kindle Fire is being shipped in strict rotation and arrives pre-configured for your Amazon account to help get you started straight away. If you don't need this level of functionality, but you like the idea of accessing your entire ebook library on the go, then watch out for the imminent release of the Kindle Paperwhite, an updated version of the original ebook reader with an improved display. You can read more about the Kindle Paperwhite on **Amazon.co.uk** and pre-order it online.

A multitude of tablet options is available in time for Christmas. Apart from the highly appealing Apple iPad, some mainstream tablet alternatives include the Google Nexus 7 and the Samsung Galaxy Note 10.1 ten-inch tablet. The Nexus 7 is hooked into Google Play, from where 600,000 Android apps and content can be downloaded. The Galaxy Note 10.1 tablet is an Android Tablet for users who don't need the walled-garden approach of Google Play or Amazon Kindle Store. Just around the corner is the new iPad Mini 7-inch tablet, rumoured for release this month.

Getting converted

Recently, when importing a local community newsletter to be published online, I was confronted by one of my least favourite file formats: a Microsoft Publisher file. This begged the question of how to open the original Publisher file without having the correct version of Publisher to begin with: and just as importantly, how to create a PDF. Coupled to this, came the news that Google Documents was dropping support for exporting files as legacy Microsoft Office formats up to Office 2003. That includes Word **.doc** and Excel **.xls** formats. File format conversion can be a headache!

Why bother running any software at all? The answer to the problem was found online at **www.zamzar.com**, a versatile file translation website that converts into almost every common file type. Images, audio, movies, web page URLs and more can be uploaded and Zamzar will convert them to a desired format. Apart from uploading over the web, you can send them as email attachments. A comprehensive rundown of filetypes is provided at: **www.zamzar.com/conversionTypes.php**

The basic Zamzar service is free with a restriction of five files totalling 100MB per session, and the results are delivered to you as download links that arrive an hour or two later. The links remain live for one day. A paid-for account offers more flexibility and starts at $7 per month and you can sign up with Paypal. Zamzar also appears to convert both to and from older Office formats (**.doc, .xls** etc) up to Office 2007 (**.docx, .xlsx**) with ease. Happily, it took my Publisher files in its stride and converted to PDF without a hitch. For those occasional file conversions, Zamzar could be a great timesaver that solves a thorny problem and is well worth bookmarking.

That concludes this month's *Net Work*. You can email Alan at **alan@epemag.demon.co.uk** or share your views with the editor at **editorial@wimborne.co.uk** for possible inclusion in *Readout*, with the chance of winning a valuable prize!

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Watch out for the taxman!

Dear editor
Further to recent comments on sourcing Australian parts, I'd like to point out to 'newbie' buyers possible costs that can apply to foreign purchases.

In addition to the cost of the parts, there is the added cost of postage and packing. In the case of Jaycar (whom I only use as a typical example, not to complain), this will be in the region of £6.50 (A$10) for a low-cost package, rising to a more typical price of about £16 (A$25) for larger packages.

So far, so 'good', this is clearly laid out on the website before any purchase is finalised and hence potential purchasers know what they are going to be charged. But, the final price you pay doesn't necessarily end there. Packets arriving from aboard are also subject to our local VAT – currently an extra 20%.

It seems that the application of this tariff is surprisingly random; you may be lucky, or you may not. If your parcel is pulled for examination of VAT, it can add up to three weeks to the delivery timetable. But, there's more! (as the adverts say). If a carrier has been used which passes the final delivery within the UK to Royal Mail, then all VAT-inspected packets will automatically attract an additional £8 admin charge – whether or not VAT was due. This is payable on delivery, which, if you are out, means a trip to the sorting office.

Royal Mail concedes that they've seen packages where the contents are only worth a couple of pounds, such as presents, but for which they still have to collect the £8 before they can be released. All in all, a much less rosy scenario than the price quoted at the foreign vendor's check out.

Of course, some parts are only available from abroad, or may be much cheaper there. I recently bought 10 surface-mount ICs from the USA: £10 each here, £3 there. Having paid $3 shipping + £8 (unexpectedly), the letter-sized package was still cheaper (just) than buying locally.

You may think that I'm bashing Jaycar or using *Silicon Chip* projects in *EPE*. I most emphatically am not. The articles are well written, informative, and above all, interesting! Keep it up.

Many years ago, (no, I'm not giving my age away!) it was a lack of diversity in UK magazine projects which led me to subscribe to US magazines such as *Circuit Cellar* and *Nuts and Volts*. I don't have any great yearning to build a wood-fired furnace controller, or some of the other esoteric projects on offer from them, but I am very interested in how they've gone about solving their problems and the circuits involved.

Indeed, these days, I tend to start looking at a new magazine from the back first, looking over the circuits presented, trying to deduce how and why they do what they do before reading any of the article text to get clues about the application. OK, so I'm 'odd', but you'd be surprised how easy it becomes to identify circuit building blocks.

Keep up the Microchip stuff!

Sally Jelfs, by email

Matt Pulzer replies:

Thank you for useful comments Sally. I too have been bitten by import VAT and administrative charges. One point worth bearing in mind is that there is no VAT on goods worth less than £15, so if ordering from abroad it is well worth requesting that this is made abundantly clear on the customs declaration (See: ***www.hmrc.gov.uk/customs/post/buying.htm****). Make sure that the value of the goods and not the total cost including P&P is quoted. That way low-value items should get through without VAT or administrative charges. For orders over £15, assume the worst (+20% + £8) – but hope for the best!*

It's also important to realise that these problems do not apply to any orders from inside the EU, where VAT at the local rate (to the order) will automatically be included at check out.

I'm delighted you enjoy EPE's *content and as you can see from the welcome return of* PIC n' Mix*, we have every intention of keeping readers supplied with regular doses of Microchip-related articles.*

Australian parts!

Dear editor
The last time I ordered from Australia, was to purchase the Mauro Grassi *Standalone CD Player*. On that occasion, Royal Mail levied the racketeering 'handling charge' of about 50% of the value of the kit for collecting the tax due on the import.

Subjected to that kind of blackmail; 'we're holding your kit hostage till you cough up', I won't be ordering from overseas again anytime soon!

Surely this rip-off could be avoided if suppliers like Jaycar included the duty in the purchase price and paid the Inland Revenue, say on a monthly basis by electronic transfer and declared the package as 'Duty paid'.

Until this happens, the articles reproduced by permission of *Silicon Chip* are not much use to me.

Ian Field, via email

Alan Winstanley replies:

The cost of brokerage (as it's called) is levied by agents once an import attracts duty and/or VAT and requires customs clearance; it's generally a flat fee per consignment. UK customs clearance is handled at the UK border, not on export from Australia. The supplier couldn't clear it into the UK directly, or if they did, I guess they'd still need a UK customs clearance agent who would demand a fee for clearing each consignment.

Short of grouping orders together to offset the brokerage fee, I can agree that brokerage (whether Royal Mail, Fedex, UPS or any other courier) and duty can be disproportionate for smaller consignments, but it's always been a fact of life and you pay it indirectly on pretty much every foreign-made item.

Alan Winstanley
EPE online editor
Readers can contact Alan by email at: **alan@epemag.demon.co.uk**

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PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C
– LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compliler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

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Ian Poole

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Among the topics covered are: A brief overview of the various versions of Windows 7. How to install and use Upgrade Advisor, which checks to see if your computer meets the minimum requirements to run Windows 7 and that your software and drivers are supported by Windows 7. How to use Windows Easy Transfer to migrate your data and settings from your Vista or XP machine to your new Windows 7 computer. Exploring Windows 7 so that you will become familiar with many of its new features and then see how they contrast with those of earlier versions of Windows. How to connect to a network and create and use Home Groups to easily share your pictures, videos, documents, etc.,with the minimum of hassle. Why Windows Live Essentials is so useful and how to download and install it. A brief introduction to Windows Media Center. The use of Action Center, which reports security and maintenance incidents. Windows Memory Diagnostic to detect the fairly common problem of faulty memory and Troubleshooting tools.

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HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold

Building your own computer is a much easier than most people realise and can probably be undertaken by anyone who is reasonably practical. However, some knowledge and experience of using a PC would be beneficial. This book will guide you through the entire process. It is written in a simple and straightforward way with the explanations clearly illustrated with numerous colour photographs.

The book is divided into three sections: *Overview and preparation* – Covers understanding the fundamentals and choosing the most suitable component parts for your computer, together with a review of the basic assembly. *Assembly* – Explains in detail how to fit the component parts into their correct positions in the computer's casing, then how to connect these parts together by plugging the cables into the appropriate sockets. No soldering should be required and the only tools that you are likely to need are screwdrivers, small spanners and a pair of pliers.

BIOS and operating system – This final section details the setting up of the BIOS and the installation of the Windows operating system, which should then enable all the parts of your computer to work together correctly. You will then be ready to install your files and any application software you may require.

The great advantage of building your own computer is that you can 'tailor' it exactly to your own requirements. Also, you will learn a tremendous amount about the structure and internal workings of a PC, which will prove to be invaluable should problems ever arise.

120 pages **Order code BP707** **£8.49**

AN INTRDUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon

eBay is an online auction site that enables you to buy and sell practically anything from the comfort of your own home. eBay offers easy access to the global market at an amazingly low cost and will enable you to turn your clutter into cash.

This book is an introduction to eBay.co.uk and has been specifically written for the over 50s who have little knowledge of computing. The book will, of course, also apply equally to all other age groups. The book contains ideas for getting organised for long term safe and successful trading. You will learn how to search out and buy every conceivable type of thing.The book also shows you how to create auctions and add perfect pictures. There is advice on how to avoid the pitfalls that can befall the inexperienced.

Cherry Nixon is probably the most experienced teacher of eBay trading in the UK and from her vast experience has developed a particular understanding of the issues and difficulties normally encountered by individuals.

So, if you are new to computers and the internet and think of a mouse as a rodent, then this is the book for you!

120 pages **Order code BP709** **£8.49**

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby

You can learn to use a computer at any age and this book will help you acheive this. It has been especially written for the over 50s, using plain English and avoiding technical jargon wherever possible. It is lavishly illustrated in full colour.

Among the many practical and useful subjects that are covered in this book are: Choosing the best computing system for your needs. Understanding the main hardware components of your computer. Getting your computer up and runnning in your home. Setting up peripheral devices like printers and routers. Connecting to the internet using wireless broadband in a home with one or more computers. Getting familiar with Windows Vista and XP the software used for operating and maintaining your computer. Learning about Windows built-in programs such as Windows Media Player, Paint and Photo Gallery.

Plus, using the Ease of Access Center to help if you have impaired eyesight, hearing or dexterity problems. Installing and using essential software such as Microsoft Office suite. Searching for the latest information on virtually any subject. Keeping in touch with friends and family using e-mail. Keeping your computer running efficiently and your valuable data files protected against malicious attack.

This book will help you to gain the basic knowledge needed to get the most out of your computer and, if you so wish, give you the confidence to even join a local computer class.

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THEORY AND REFERENCE

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS
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Mike Tooley

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The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages **Order code NE43** **£25.99**

BEBOP TO THE BOOLEAN BOOGIE
Third Edition
Clive (Max) Maxfield

This book gives the 'big picture' of digital electronics. This indepth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

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Clive (Max) Maxfield and Alvin Brown

CD-ROM

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C. R. Robertson

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The book explains all theory in detail and backs it up with numerous worked examples. Students can test their understanding with end of chapter assignment questions for which answers are provided. In this new edition, the layout has been improved and colour has been added. A free companion website with additional worked examples and chapters is also available.

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STARTING ELECTRONICS – 4th Edition
Keith Brindley

Starting Electronics is unrivalled as a highly practical introduction for technicians, non-electronic engineers, software engineers, students, and hobbyists. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits. Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of readily available, inexpensive components makes this practical exploration of electronics easily accessible to all levels of engineer and hobbyist.

Other books tell readers what to do, but sometimes fail to explain why - Brindley gives readers hands-on confidence in addition to real scientific knowledge, and insight into the principles as well as the practice. All written explanations and steps are supplemented with numerous photos, charts, tables and graphs. Concepts and practical aspects are explained thoroughly with mathematical formulae and technical schematic drawings.

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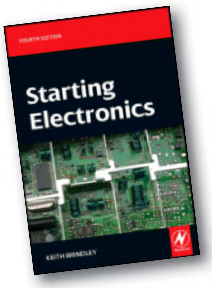

MUSIC, AUDIO AND VIDEO

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett
Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

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Ian Waugh
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Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

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Ian Waugh
All modern music recordings use digital audio technology. Now everyone with a computer can produce CD-quality recordings and this book shows you how.
Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available, and how to achieve professional results.

It explains:
- What computer system you need
- Sound and digital audio essentials
- What to look for in a sound card
- What effects to use
- The art of mixing
- Recording techniques
- How to use virtual instruments
- How to edit audio and create loops

Computer-based recording is the future of music and this book shows how you can join the revolution now.

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We also carry a selection of books aimed at readers of *EPE*'s sister magazine on vintage radio *Radio Bygones*. These books include, the four volumes of our own *Wireless For the Warrior* by Louis Meulstee. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.
For details see the UK shop on our web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

PROJECT BUILDING AND TESTING

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** £5.99

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** £29.00

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** £5.45

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** £5.49

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NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

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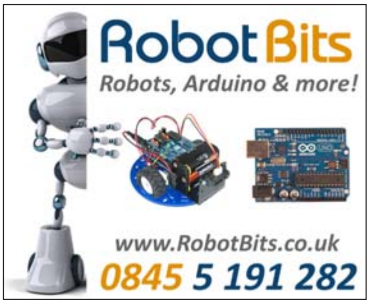

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Next Month

Content may be subject to change

Low Capacitance Adaptor for DMMs

This neat little adaptor allows a standard digital multimeter to measure low values of capacitance – from less than a picofarad to over 10nF. Measure tiny capacitors or stray capacitances in switches, connectors and wiring. How have you survived without it?

3-Input Stereo Audio Switcher

Need more analogue audio inputs for your stereo amplifier or home-theatre set-up? This 3-Input Stereo Audio Switcher will do the job beautifully. It works with an infrared remote control or you can just press one of the front-panel buttons to select a source.

Stereo Compressor

Do you hate the way the sound level on your TV suddenly jumps during the advert breaks? Or do you find that the sound levels vary widely when switching between digital TV stations? This Stereo Compressor will solve that problem. It reduces the dynamic range of the signal while still maintaining clean sound.

Universal USB Data Logger – Part 2

Next month, we assemble our multipurpose analogue/digital data logger, explain how to install the Windows driver and PC host software, and describe how the unit is used.

Jump Start – iPod Amp

Fancy an audio project, but not on the scale of a switcher or compressor? We've got just the challenge for you with our iPod Amp; a fun and easy project for all levels of experience. This will be Mike and Richard Tooley's ninth project in our series dedicated to newcomers, or those following courses taught in schools and colleges.

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